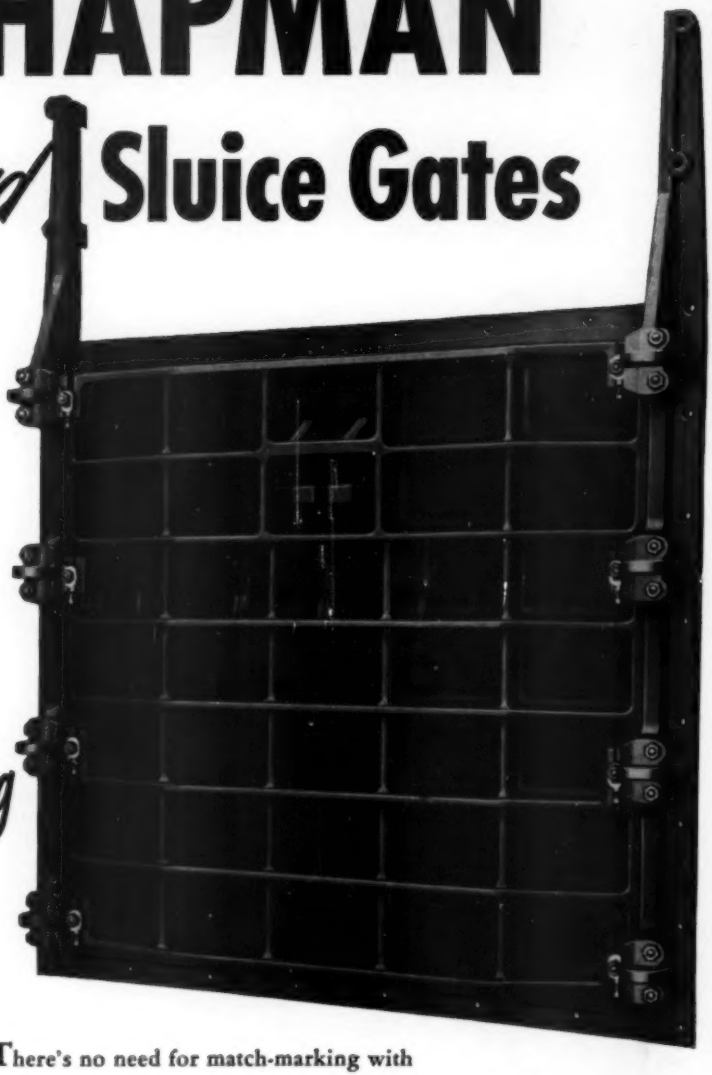
WATER & SEWAGE WORKS

WATER SUPPLY • INDUSTRIAL WASTE TREATMENT • SEWAGE DISPOSAL

CHAPMAN

Standard Sluice Gates



Have Interchangeable Parts that Eliminate Match-Marking

There's no need for match-marking with Chapman standardized Sluice Gates — stem and couplings are completely interchangeable. All repairs and replacement parts can be easily installed in the field *without alterations.*

Depending on your needs, these Chapman Sluice Gates may be operated by hand, hydraulic cylinder or motor unit. The motor unit comes completely wired — ready for installation. For additional information write . . . *today!*

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INDIAN ORCHARD, MASSACHUSETTS

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AT THE

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We invite you to meet and greet old friends and new in our exhibit area. Our facilities are at your disposal. Feel free to use them.

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Mathieson
CHEMICALS

2081

SERVING INDUSTRY, AGRICULTURE AND PUBLIC HEALTH

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WATER & SEWAGE WORKS

WATER SUPPLY • SEWAGE DISPOSAL
INDUSTRIAL WASTE TREATMENT

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155 E. 44th St., New York 17, N.Y.
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An illustrated brochure with detailed specifications showing our complete line of Waterworks Brass will be sent to you promptly on request. A. Y. McDONALD MFG. CO., Dubuque, Iowa.

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EST. 1856

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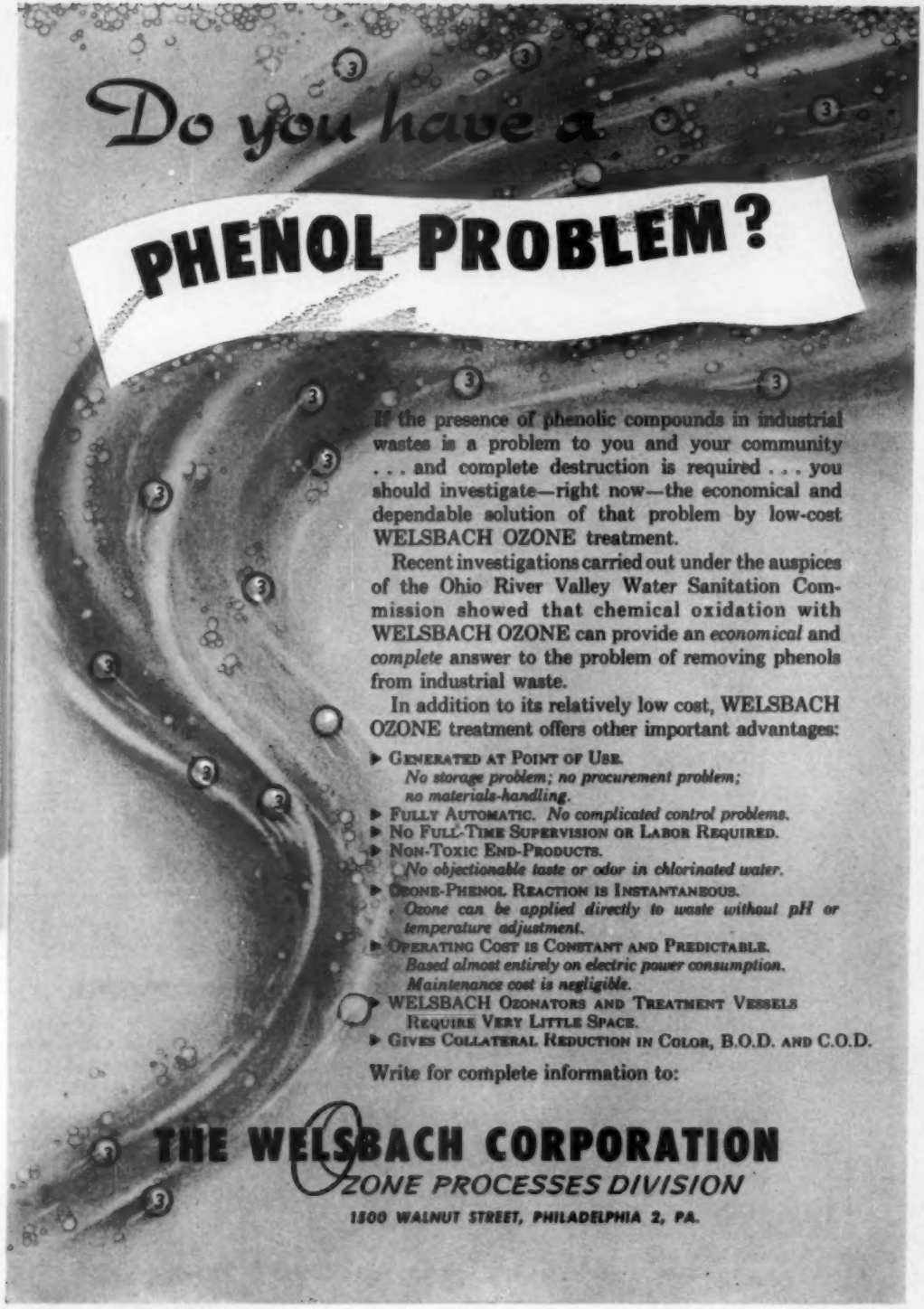

If the presence of phenolic compounds in industrial wastes is a problem to you and your community . . . and complete destruction is required . . . you should investigate—right now—the economical and dependable solution of that problem by low-cost WELSBACH OZONE treatment.

Recent investigations carried out under the auspices of the Ohio River Valley Water Sanitation Commission showed that chemical oxidation with WELSBACH OZONE can provide an *economical* and *complete* answer to the problem of removing phenols from industrial waste.

In addition to its relatively low cost, WELSBACH OZONE treatment offers other important advantages:

- GENERATED AT POINT OF USE.
  No storage problem; no procurement problem; no materials-handling.
- FULLY AUTOMATIC. *No complicated control problems.*
- NO FULL-TIME SUPERVISION OR LABOR REQUIRED.
- NON-TOXIC END-PRODUCTS.
  No objectionable taste or odor in chlorinated water.
- OZONE-PHENOL REACTION IS INSTANTANEOUS.
  Ozone can be applied directly to waste without pH or temperature adjustment.
- OPERATING COST IS CONSTANT AND PREDICTABLE.
  Based almost entirely on electric power consumption. Maintenance cost is negligible.
- WELSBACH OZONATORS AND TREATMENT VESSELS REQUIRE VERY LITTLE SPACE.
- GIVES COLLATERAL REDUCTION IN COLOR, B.O.D. AND C.O.D.

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OZONE PROCESSES DIVISION
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THE RIO GRANDE DE LOIZA DEVELOPMENT—OUR SEVENTH SERVING THE GREATER SAN JUAN AREA

. . . interior view of control tables

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Another triumph of progress and engineering skill was marked during the recent opening of the Puerto Rico Aqueduct and Sewer Authority's colorful Rio Grande De Loiza filter plant. Roberts Filter is proud to have taken part in this 30 million gallon per day project—seventh with which we have been identified over a period of 35 years in the historic San Juan area.

in cooperation with

SERGIO CUEVAS
Executive Director of Puerto Rico Aqueduct and Sewer Authority

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Offers 8 BIG ADVANTAGES for Coagulation

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4. **Helps reduce tastes and odors**
5. **Removes organic color from water**
6. **Has no chlorine demand, because the aluminum ion has no reduced state**
7. **Stores well and remains free-flowing for uniform feeding**
8. **Is low in cost**

The most widely-used coagulant for freeing water from turbidity, color and similar impurities is General Chemical Aluminum Sulfate. That's because this quality product—with a reputation spanning half a century—is always uniform . . . always meets the strictest chemical and physical specifications. And it is always readily available from convenient producing and shipping locations America over. For your requirements—to be sure of the source—specify General Chemical "Alum"!

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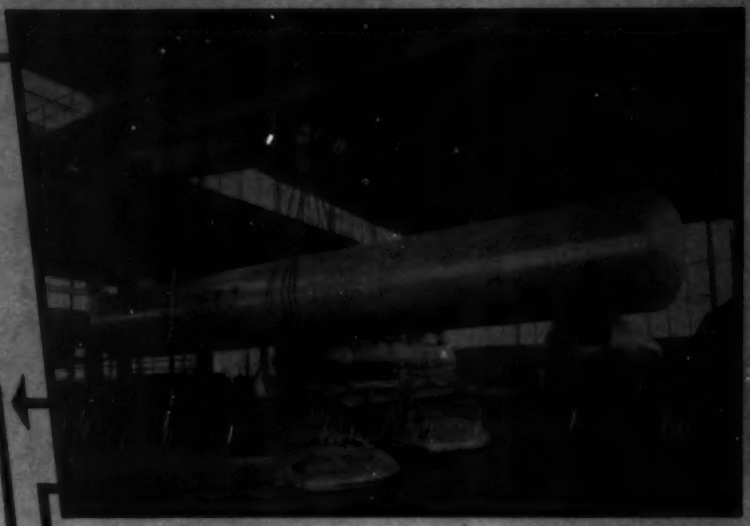
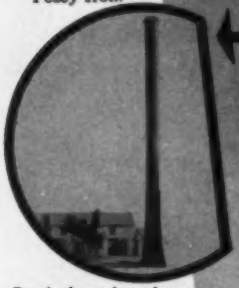
POSEY EQUIPMENT EXPEDITES

Quicker Posey Delivery Dates

200,000 gallon elevated tank— by Posey Iron.



This 50-ton crane (27-foot headroom) allows quick, easy handling of sizeable units like this butane tank.



Stacks have long been a specialty at the Posey Iron Works.

Expanding production finds Posey ready with a plant recently modernized. Among outstanding equipment units at the Posey Iron Works are the following:

(1) 32 foot roll for bending steel plate.
(2) 16 foot power brake for ½" steel plate.
(3) 50-ton crane with 27-foot headroom.
(4) 16' 6" vertical boring mill.
(5) Giant lathe — 30' length x 94" diameter.

Posey equipment is housed in plants covering 16½ acres under roof. The right equipment plus adequate plant space — these protect your deliveries at Posey. Write today for free, 12-page reference bulletin.

Posey stainless clad digester —13' O.D. x 40' long.

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A warm welcome awaits you at the booth where R. D. Wood products will be on display. We are looking forward to showing you the famous Mathews replaceable barrel—a feature that is incorporated in the hydrants of the modern fire-fighting system of the city of Miami.

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Made by R. D. Wood Company
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Manufacturers of "Sand-Spun" Pipe (centrifugally cast in sand molds) and R. D. Wood Gate Valves

Fluoridation News

1945 1951

IN TEXAS, TOO—

CITY OF MARSHALL

MARSHALL, TEXAS

January 24th, 1951

Wallace & Tiernan Co. Inc.
1112 National City Bldg.
Dallas 1, Texas

Gentlemen:

The City of Marshall, Texas began fluoridation of its municipal water supply in the Spring of 1946, under the jurisdiction of the Texas State Health Department. Marshall was the first city in the State of Texas to use fluoridation.

In February 1950, we changed our method of fluoridation by feeding sodium fluoride with a Wallace & Tiernan Type NA Dry Chemical Feeder.

We have found the Wallace & Tiernan Type NA Feeder to be simple in operation, easy to adjust and maintain, and extremely accurate for feeding sodium fluoride. We have been able to hold the fluoride content of our treated water very constant by using this feeder.

We would be glad to recommend this feeder to any town considering adding fluorides to the public water supply.

Very truly yours,

CITY OF MARSHALL
J.W. Schonhardt
J.W. SCHONHARDT
Water Superintendent

When *your* community is ready to look into fluoridation — and after you have consulted your State Department of Health — you'll find W&T Engineers ready and willing to help you.

WISCONSIN

WALLACE & TIERNAN
COMPANY, INC.
CHLORINE AND CHEMICAL CONTROL EQUIPMENT
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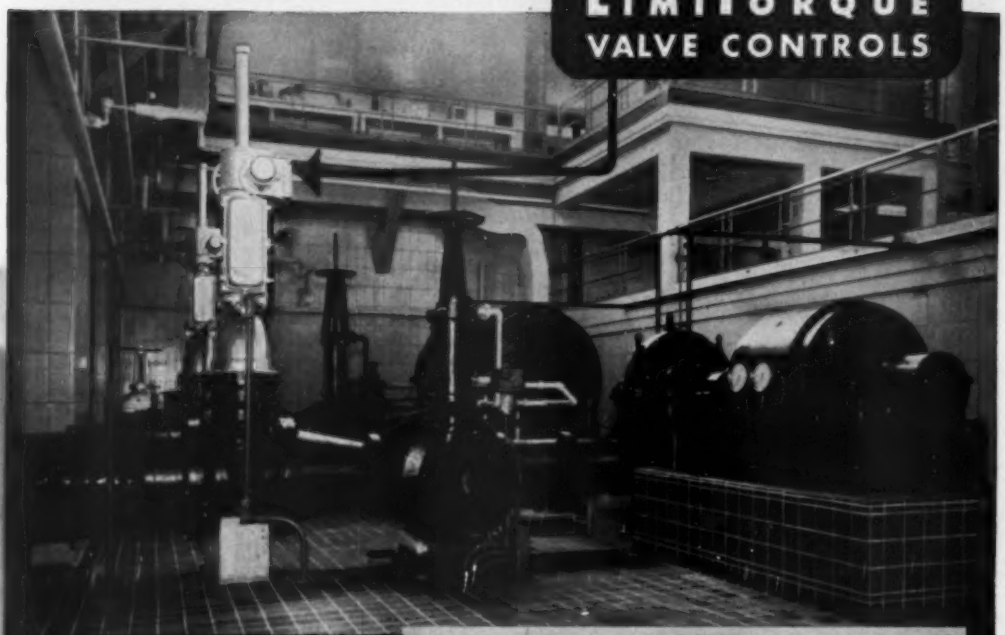
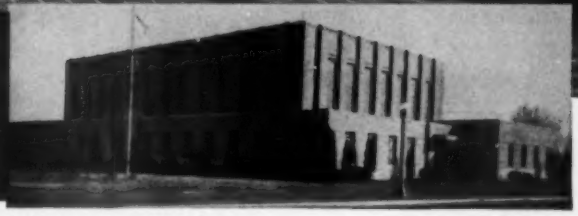
PHILADELPHIA PICKS PHILADELPHIA LIMITORQUE VALVE CONTROLS



. . . for the New TORRESDALE FILTERED WATER PUMPING STATION



Here, as at so many other modern water works stations throughout the country, LimiTorque Controls were selected for valve operation.

LimiTorque Remote Control permits one man to open and close large or inaccessible valves by merely pushing a button. All the while he can see the status of each valve on a panelboard. This saves considerable time and manpower and assures a better coordination of plant operation.

Damage to seats, stems, discs, etc., is prevented because LimiTorque shuts off the power if an obstruction occurs.

LimiTorque fits all types of valves and may be actuated by any available power source such as electricity, gas, water, air, steam, etc.

Your valve manufacturer can supply them.

Valves shown with LimiTorque Controls were made by A. P. Smith Co.

Write for a copy of LimiTorque Catalog L-50 which gives full details of all types of LimiTorque Controls. Please write on your Business Letterhead.

Philadelphia Gear Works, INC.

ERIE AVE. AND G ST., PHILADELPHIA 34, PA.
NEW YORK • PITTSBURGH • CHICAGO • HOUSTON
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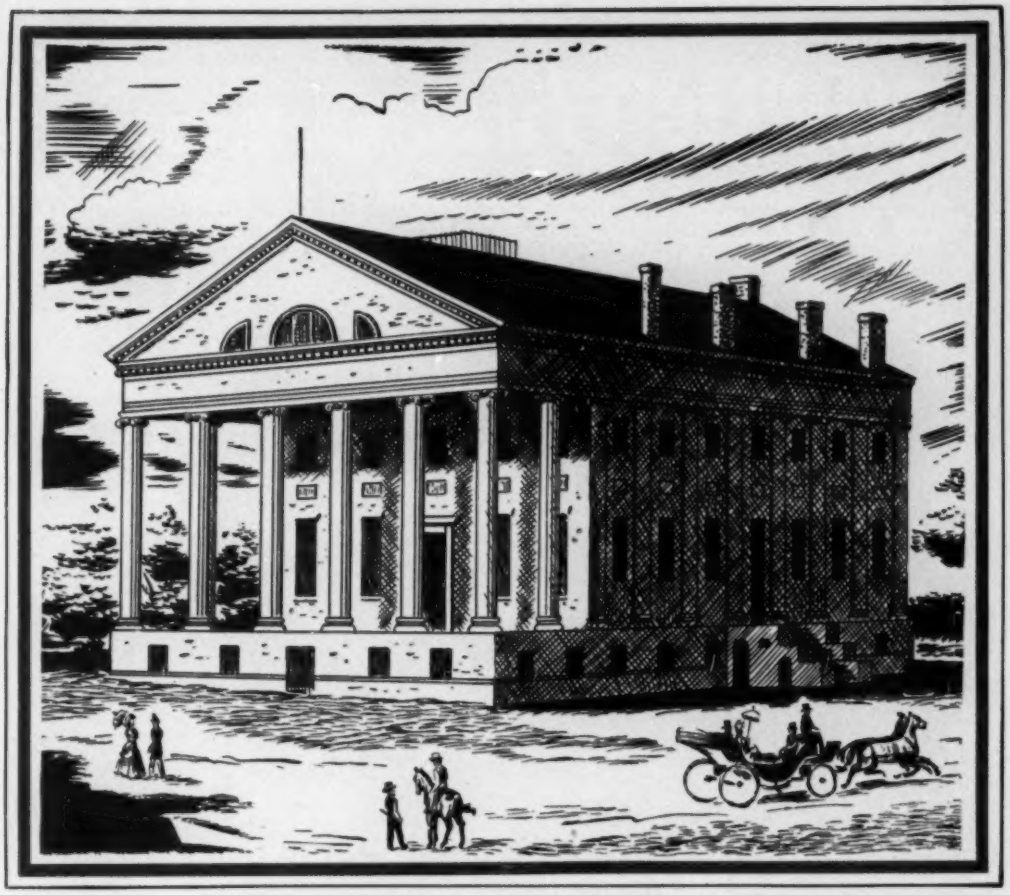
Industrial Gears and Speed Reducers
LimiTorque Valve Controls



Richmond's State Capitol, completed in 1792, as it looked 100 years ago

Richmond, Virginia, has a cast iron water main in service that was installed well over a century ago. In those stage-coach days, *traffic shock* caused by heavy trucks and buses was, of course, undreamed of. There were no sewers and other underground conduits to cause soil disturbances and settlement. Yet this rugged old pipe had what it takes in shock-strength and beam-strength to meet unforeseen stresses. Strength, as well as effective resistance to corrosion, are prerequisites of long life in pipe to be laid under city streets. This is evidenced by the fact that cast iron water and gas mains, laid over a century ago, are still serving in the streets of more than 30 cities in the United States and Canada.

United States Pipe and Foundry Co.,
General Offices, Burlington, N. J.
Plants and Sales Offices Throughout the U. S. A.

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PIPE

NUMBER FOUR OF A SERIES

SIMPLICITY of AMERICAN METERS

MEANS A SMALLER STOCK OF PARTS

With fewer moving parts and a more simple construction than most water meters, maintenance and repair cost of American Meters is unusually low. Parts stocks are kept at the absolute minimum both for number of items and quantity of each one.

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Write for full details.

BUFFALO METER CO.

2909 MAIN STREET, BUFFALO 14, NEW YORK

MUELLER WATER WORKS GOODS

HIGHEST QUALITY MATERIALS.
SOUND, PRACTICAL DESIGN.
PRECISION MANUFACTURING.

MANY EXCLUSIVE FEATURES.
CAREFUL INSPECTION.
THOROUGH TESTING.

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Lead Flange Couplings, Solder Nipples, Brass Plugs

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Sluice Gates and Operating Mechanisms

Regulators and Relief Valves

DEPENDABLE SINCE 1857 FULLY WARRANTED OUR 93rd YEAR

MUELLER CO.

MAIN OFFICE AND FACTORY ..... DECATUR, ILLINOIS
OTHER FACTORIES: *Los Angeles, Cal.; Chattanooga, Tenn.; Sarnia, Ont., Canada*

Like a Percheron draft horse cast iron pipe is known for strength

Long life and low maintenance cost of mains laid under city streets depend not only on effective resistance to corrosion but on definite strength factors. The four strength factors that pipe must have to withstand beam stress, external loads, traffic shocks and severe working pressures, are listed on the page opposite. No pipe that is deficient in any of these strength factors should ever be laid in paved streets of cities, towns or villages. Cast iron water and gas mains, laid over a century ago, are serving in the streets of more than 30 cities in the United States and Canada. Such service records prove that cast iron pipe not only resists corrosion but combines all the strength factors of long life with ample margins of safety.

CAST IRON PIPE

in pipe for city streets

No pipe that is deficient in any of the following strength factors should ever be laid under paved streets.

CRUSHING STRENGTH

The ability of cast iron pipe to withstand external loads imposed by heavy fill and unusual traffic loads is proved by the Ring Compression Test. Standard 6-inch cast iron pipe withstands a crushing weight of more than 14,000 lbs. per foot.

BEAM STRENGTH

When cast iron pipe is subjected to beam stress caused by soil settlement, or disturbance of soil by other utilities, or resting on an obstruction, tests prove that standard 6-inch cast iron pipe in 10-foot span sustains a load of 15,000 lbs.

SHOCK STRENGTH

The toughness of cast iron pipe which enables it to withstand impact and traffic shocks, as well as the hazards in handling, is demonstrated by the Impact Test. While under hydrostatic pressure and the heavy blows from a 50 pound hammer, standard 6-inch cast iron pipe does not crack until the hammer is dropped 6 times *on the same spot* from progressively increased heights of 6 inches.

BURSTING STRENGTH

In full length bursting tests standard 6-inch cast iron pipe withstands more than 2500 lbs. per square inch internal hydrostatic pressure, which proves ample ability to resist water-hammer or unusual working pressures.

CAST IRON PIPE RESEARCH ASSOCIATION, THOS. F. WOLFE, MANAGING DIRECTOR, 122 SO. MICHIGAN AVE., CHICAGO 3.

SERVES FOR CENTURIES

ANACONDA METALS

for sewage and water works equipment

Various standard and certain special ANACONDA Metals manufactured by The American Brass Company are finding increasing use as materials for sewage treatment and water works equipment.

For almost a quarter century EVERDUR* Metal, the original copper-silicon alloy group, has been used increasingly for sewage and water works equipment, where its unusual physical and chemical properties have earned it an enviable reputation for long-lived, economical service under severely corrosive operating conditions. These high-strength, easily-welded Everdur alloys make possible the use of lightweight wrought assemblies which will outlast cast, rustable equipment many times over.

The following tables summarize briefly other ANACONDA Products suitable for sewage treatment and water works equipment.

FOR WATER WORKS EQUIPMENT

SERVICE	FORM	MATERIAL
Reservoir outlet screens	Wire mesh	Everdur 1010
Screen frames	Bar	Everdur 1010
Weir screens	Plate, Tube Special shape wire Rod	85 Red Brass Everdur 1010
Filter distribution lines	Pipe	85 Red Brass
Winding wire for vacuum filter	Wire	Copper Phosphor Bronze 361 Everdur 1015
Vacuum filter piping	Pipe Tube	85 Red Brass Copper
Vacuum filter vat	Sheet	Copper Everdur 1010
Service lines	Pipe Tube	85 Red Brass Copper
Valve and gate stems	Rod	Tobin Bronze Leaded Naval Brass Everdur 1012 or 1014 Manganese Bronze 937
Studs, bolts and nuts	Rod	Naval Brass Everdur 1010 and 1015
Guides, seats, sealing strips	Bars Shapes Strips	Naval Brass Manganese Bronze 937 Everdur 1010

FOR SEWAGE TREATMENT

SERVICE	FORM	MATERIAL
Pump galleries, over tanks, screen rooms, etc.	Rigid conduit & E.M.T.	Everdur 1015
Coarse bar screen enclosures	Sheet	Everdur 1010
Grit chamber proportional weir	Sheet	Everdur 1010
Weirs and brackets in sedimentation tanks	Sheet	Everdur 1010
Gates	Sheet Rod Angles Channels	Everdur 1010 Everdur 1010 Everdur 1010 Everdur 1010
Air lines for aeration tanks	Pipe and Tube	85 Red Brass & Copper
Meter and control lines	Tube	Copper
Sampling tubes for digesters	Tube	Copper
Heating coils for digesters	Tube	Copper
Hangers and fittings for heating coils	Rod	Everdur 1010 and 1015
Sludge gas lines	Pipe	85 Red Brass
Valve and gate stems	Rod	Tobin Bronze* Leaded Naval Brass Everdur 1012 or 1014 Manganese Bronze 937
Studs, bolts and nuts	Rod	Naval Brass Everdur 1010 or 1015
Guides, seats, sealing strips	Bars Shapes Strips	Naval Brass Manganese Bronze 937 Everdur 1010
Manhole steps and anchors	Rods	Everdur 1015

THE TECHNICAL DEPARTMENT of The American Brass Company will gladly cooperate in helping you select the most suitable copper-base alloys for sewage treatment and water works equipment. Address: The American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario. 2140

Where corrosion resistance counts—consider

EVERDUR

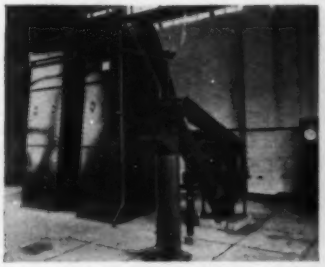
COPPER-SILICON ALLOYS

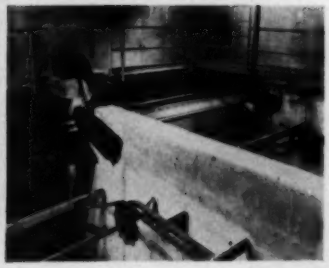
*Reg. U. S. Pat. Off.

The treatment of water and sewage by mechanical means has definitely proved most effective and economical — is the accepted practice in practically all modern plants. Jeffrey Sanitation Engineers are Specialists — treat each case in a practical way — are qualified by experience to offer technical information on equipment and plant design. Send for list of Jeffrey-equipped plants now giving day-in and day-out service.

a treat to get right treatment

for instance





The five photos show the application of Jeffrey Screens, Collectors, Scum Removers and Grit Washers in both large and small plants. Also Sludge Elevators, Chemical Feeders, Screenings Grinders and equipment for biofiltration plants. Catalog No. 775-A goes into detail.

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Jeffrey Mfg. Co., Ltd., Montreal, Canada
Jeffrey-Galion (Pty.) Ltd., Johannesburg, S.A.
The Ohio Malleable Iron Co., Columbus, Ohio
British Jeffrey-Diamond Ltd., Wakefield, England
The Galion Iron Works & Mfg. Co., Galion, Ohio
The Kilbourne & Jacobs Mfg. Co., Columbus, Ohio

Worth its weight

JOHNS-MANVILLE PRODUCTS

Johns-Manville

. . . in installation savings

Are you finding it increasingly difficult, in the face of today's economy, to undertake needed water-line construction?

If so, you may find—as other planners do—that Transite* Pressure Pipe can help provide a practical answer to your problem. For this pipe, in addition to its continuing, long-term savings, offers an opportunity for economies in installation *that may go far in helping you contend with rising costs and manpower shortages.*

Transite Pressure Pipe offers a combination of advantages which speed and facilitate water main installations all along the line—from the time the pipe is first received, to final placement of the line in service and restoration of normal street traffic. Not only do pipe laying crews find this modern pipe easy to work with, but its unique features make for a more compact, efficient and economical operation in virtually all the construction phases of water-line extension projects.

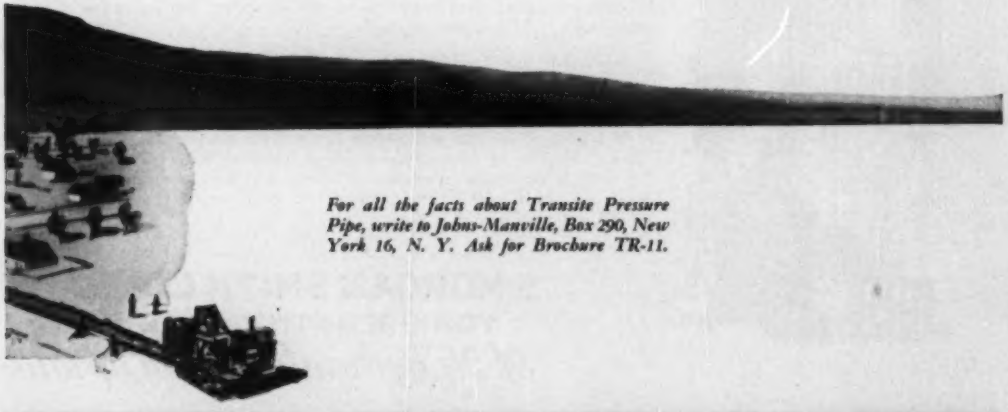
Economies start as soon as a shipment of Transite Pipe is received. Because it is light in weight, unloading and other handling operations are simplified. More footage can be carried per truckload, trucking costs are lowered, and distribution on the job site is faster. And except for the larger diameters of pipe, the sections can be lowered into the trench by hand, or with the aid of rope slings.

Assembly, too, is both rapid and economical. The flexibility of Transite's joints permit the pipe to be laid around wide curves without the need for special fittings. The Simplex Couplings require no calking or hot compounds; they are quickly and easily assembled to provide lastingly tight joints. *And with this pipe you can check for proper assembly immediately after the pipe ends are joined.*

Makes pipe-laying an assembly-line operation

This combined feature of rapid assembly and assurance of joint-tightness as fast as the line is laid, is the key to an important Transite advantage: it means that trench excavation, pipe laying, and backfilling operations can follow in quick succession—often under the supervision of one foreman. It makes pipe-laying virtually an assembly-line operation in which the trench can be closed in a minimum of time. This assures more economical use of excavation and earth handling equipment, reduces the expense and hazards of long stretches of open trench, and helps button-up the job with the least possible expenditure of time, labor and money.

These *initial* savings . . . plus the *long term* economies that have been effected in thousands of installations . . . are two good reasons why you should have the complete story about this modern asbestos-cement pipe developed and produced by Johns-Manville to carry water more efficiently and more economically.



For all the facts about Transite Pressure Pipe, write to Johns-Manville, Box 290, New York 16, N. Y. Ask for Brochure TR-11.

TRANSITE PRESSURE PIPE

*Transite is a registered Johns-Manville trade mark

WHEN Millions Live As One

ADVENTURESOME folk, since the beginning of time, have migrated . . . Settling in tiny clusters . . . Spreading spider-web fashion to dot the land with villages and towns . . . While others pressed forward, facing dangers concealed behind each rock and tree!

But with the growth of cities, new perils arose and multiplied . . . People were living too closely together . . . Epidemics and pestilence exacted their toll . . .

Then science and modern machinery rescued them from exposure to disease emanating from impure water and unsanitary waste disposal . . . And, today, *millions live as one!*

Rotovalves and Axial Flow Pumps, by Smith, are in service—controlling water, controlling floods and regulating sewage discharge, in important systems, far and wide.

The recognition and acceptance given these products are not accidental. They come from superior design, resulting from our more than 75 years of hydraulic experience . . . Facts that are significant, because they are proof positive of our ability to serve you, *if you place your problem in our hands!*

S·MORGAN SMITH COMPANY
YORK·PENNSYLVANIA ~ U·S·A·
If It's Hydraulics-Put It Up to Us·

POWER by SMITH

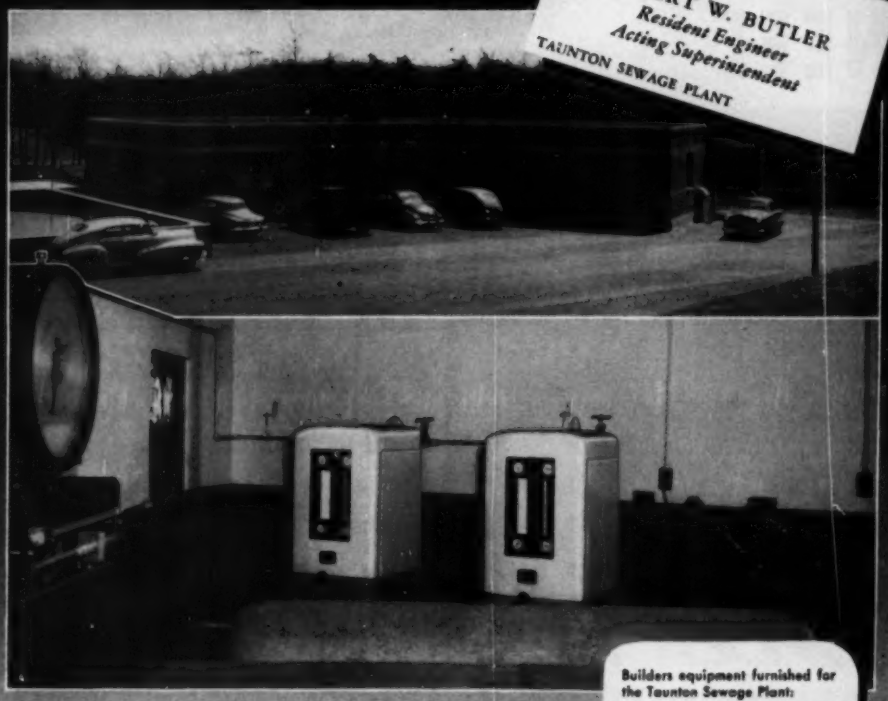
TAUNTON, MASS.

Sewage Plant

(COMPLETED IN 1950)

FAY, SPOFFORD & THORNDIKE
Engineers
BOSTON, MASS.

ROBERT W. BUTLER
Resident Engineer
Acting Superintendent
TAUNTON SEWAGE PLANT



The Taunton River, once famous for its herring run, had for years been seriously polluted by untreated sewage from the city of Taunton. This modern sewage treatment plant handles storm water as well as sanitary sewage. The efficiency of this plant has notably decreased pollution in the receiving stream. The Taunton Board of Sewer Commissioners, Edward J. Dahill, Chairman, is proud of its part in the advancement of the Massachusetts pollution abatement program.

To serve approximately 38,000 people, this plant treats a normal dry weather flow of 3.5 MGD, but is capable of handling peak flows of 10 MGD. The treatment process involves grit and grease removal, settling, sludge digestion, sludge drying, and disinfection of final effluent. Builders Sewage Works Equipment, installed by Gil Wyner Co., Inc. of Malden, Mass., is employed for flow metering and chlorination of plant effluent. For Bulletins and complete information on Builders equipment, address Builders-Providence, Inc. (Division of Builders Iron Foundry), Prov. 1, R. I.

Builders equipment furnished for the Taunton Sewage Plant:

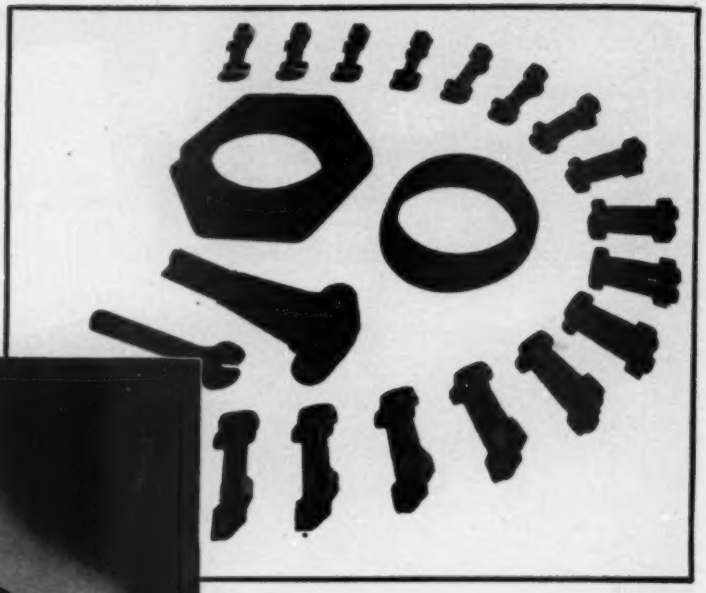
- CVS Chlorinisors, 400 lbs. per 24 hr. max. capacity each. See photo.
- 20" x 10" Venturi Tube with Type M Register-Indicator-Recorder for Raw Sewage
- 8" x 3½" Venturi Tube and Chronoflo Transmitter and Receiver (Totalizer-Indicator-Recorder) for Primary Sludge
- 8" x 3½" Venturi Tube and Chronoflo Transmitter and Receiver (Totalizer-Indicator-Recorder) for Digested Sludge
- 6" x 3½" Venturi Tube and Chronoflo Transmitter and Receiver (Totalizer-Indicator-Recorder) for Supernatant Liquor
- Main Instrument Panel for Chronoflo Receivers

B·I·F INDUSTRIES

BUILDERS-PROVIDENCE

BUILDERS

ALL YOU NEED



IS: A RATCHET AND OPEN END WRENCH, THREE RUBBER GASKETS, THREE CAST IRON FOLLOWER RINGS AND A HAND FULL OF BOLTS AND NUTS ***TO INSTALL***

the New
SMITH CUT IN VALVE AND SLEEVE

Gone are the days of—large costly excavations—melting furnaces and pouring pots—pouring and caulking lead joints—when the New All Mechanical Joint Smith Cut In Valve and Sleeve is used.

The Cut In Valve can be installed rapidly, in fair or stormy weather on Cast Iron A.W.W.A. and Federal specification water mains, by unskilled labor, using only two wrenches.

Moulded rubber gaskets fit into machined "Stuffing Box" type joints, guaranteeing a permanent leak-proof seal.

Smith Cut In Valves are manufactured in compliance with the A.W.W.A. Gate Valve specification, and all parts are interchangeable with like parts of Smith A.W.W.A. Gate Valves.

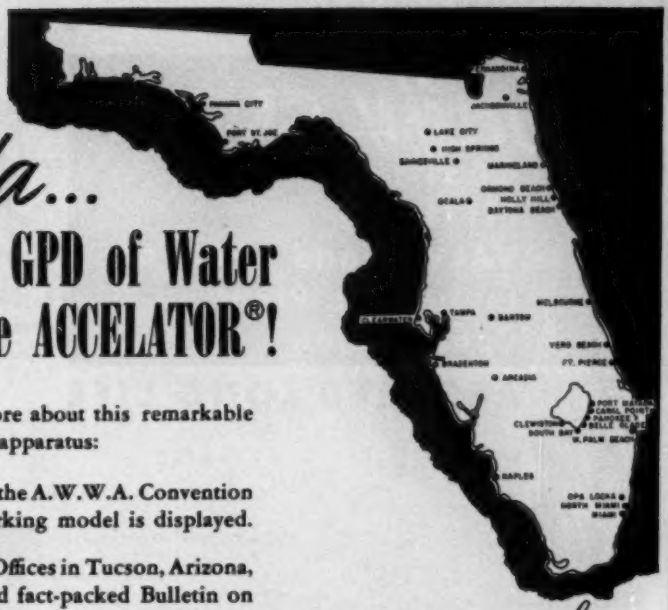
Write for Bulletin No. MJ2.

34

FIRE HYDRANTS · VALVES · SINCE 1896

THE A.P. SMITH MFG. CO.

EAST ORANGE, NEW JERSEY



In Florida...

Over 100,000,000 GPD of Water Is Treated By The ACCELATOR®!

Here's how you can learn more about this remarkable high-rate water conditioning apparatus:

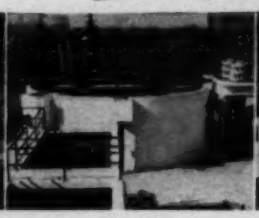
- Visit the Infilco Booth at the A.W.W.A. Convention where a transparent working model is displayed.
- Write Infilco's Executive Offices in Tucson, Arizona, for a 28-page picture and fact-packed Bulletin on the Accelator.

SERVING THE WATER TREATMENT REQUIREMENTS OF INDUSTRIES AND MUNICIPALITIES WITH EQUIPMENT THAT'S .....

Quality Engineered for Quality Performance

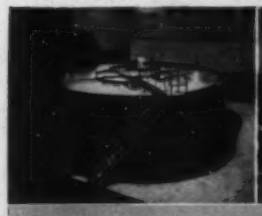
CITY OF GAINESVILLE

CITY OF TAMPA

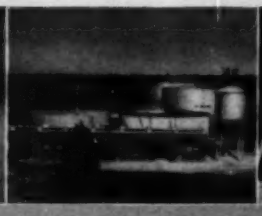


CITY OF OCALA

CITY OF BRADENTON



NATIONAL CONTAINER CORP. JACKSONVILLE



ST. JOE PAPER CO. PORT ST. JOE

CITY OF BELLE GLADE

INFILCO INC.

TUCSON, ARIZONA

WITH OFFICES IN PRINCIPAL CITIES

INFILCO

• BETTER WATER CONDITIONING AND WASTE TREATMENT SINCE 1891 •

WORLD'S LEADING MANUFACTURERS OF WATER CONDITIONING AND WASTE TREATING EQUIPMENT

for replacements or new installations

Specify CLOW

CAST IRON PIPE, FITTINGS, VALVES and SPECIALS In Sewage Plant Construction

CLOW FLANGED END FLAP VALVE—Also comes with Bell or Spigot End. Flap valves are bronze mounted, are superior in meeting most field conditions, may be easily dismounted for repairs if found necessary at any time.

ASSURED LONG LIFE

for a century or more

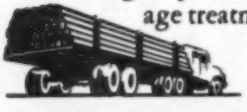
CLOW BELL END SLUDGE SHOE—Also comes with Flanged End. Improved Sludge Shoes are extra strong, have maximum sludge opening, and the flare reduces entrance losses to a minimum.

CLOW PRESSURE RELIEF VALVES—Cover retained in operating position at all times by means of internal arrangement. Made with removable grated bottom to allow water only to enter tank. Made any length desired.

CLOW FLANGE AND FLARE ELBOW—Are regularly furnished with flange faced and drilled to A.S.A. Class 125 Standard template. Bell and flare elbows can also be furnished.

CLOW SPECIAL CAST IRON PIPE AND FITTINGS

James B. Clow & Sons make a great many special cast iron fittings of irregular shapes in sizes up to 54", conforming to engineering details submitted by the purchaser and to meet the unusual requirements of pipe line specifications often presented in such types of construction as Filtration and Sewage Disposal Plants. Clow also manufactures Cast Iron Pipe in steel pipe sizes 3 through 10 inches (I.P.S. pipe) which has the same outside diameter as common steel pipe. I.P.S. pipe can be cut, threaded, and fabricated on the job with ordinary tools of the piping trade. Write for the Clow Catalog "Pipe Economy" which fully illustrates our line of Cast Iron Pipe, Fittings, Specials and Valves for use in sewage treatment plant construction. Ask Clow for price and delivery on your needs.



CLOW CAST IRON PIPE FITTINGS

All types of Clow Cast Iron Pipe Fittings are offered in straight and reducing sizes for use with Bell and Spigot Joint, Mechanical Joint and Flanged Joint Cast Iron Pipe in sizes up to 24".

Illustrations below are Typical Fittings

CLOW BELL & BELL ONE EIGHTH BEND

CLOW MECHANICAL JOINT 90° ELBOW

CLOW 90° STANDARD FLANGED ELBOW

JAMES B. CLOW & SONS

201-299 North Talman Avenue

CAST IRON

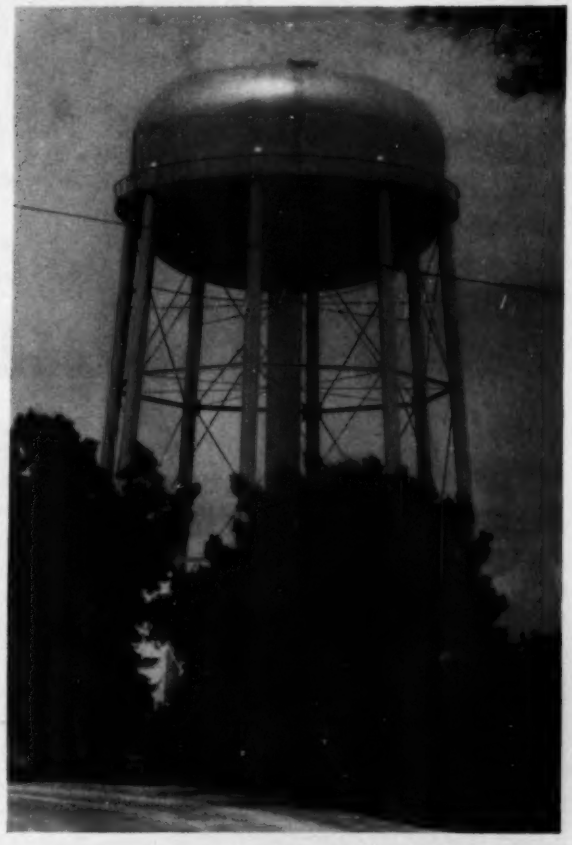
Chicago 80, Illinois

National Cast Iron Pipe Division, Birmingham, Ala.; subsidiaries Eddy Valve Company, Waterford, N.Y.; Iowa Valve Co., Oskaloosa, Iowa

BETTER WATER SERVICE

in the heart of vacationland

New Horton Tank in St. Petersburg Beach



Florida is truly the heart of America's southern vacationland. Each year thousands of sun-hungry travelers fill its cities to capacity. Some areas are doubled in population . . . others trebled in a period of weeks.

This great influx of people would strain municipal facilities unless adequate provisions were made. That's one reason why a Horton elevated water tank was installed at St. Petersburg Beach on Long Key. This 500,000 gallon structure gives more dependable water service throughout the year.

Many cities find that elevated water storage facilities increase the water pressure and keep distribution pressures more uniform.

Horton elevated tanks are built with ellipsoidal bottoms in capacities from 15,000 to 500,000 gallons . . . and with radial-cone bottoms from 500,000 to 3,000,000 gallons.

HORTON

WELDED STEEL

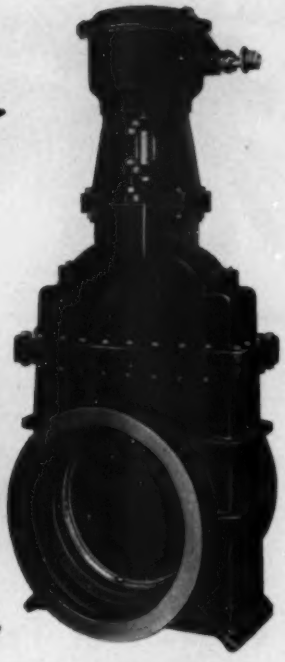
STORAGE TANKS

CHICAGO BRIDGE & IRON COMPANY

Plants in Birmingham, Chicago, Salt Lake City, and Greenville, Pa.

Atlanta 3	2181 Healey Building	Los Angeles 14	1565 General Petroleum Building
Birmingham 1	1586 North Fiftieth Street	New York 6	3290-165 Broadway Building
Boston 10	1040-201 Devonshire Street	Philadelphia 3	1644-1700 Walnut Street Building
Chicago 4	2198 McCormick Building	Salt Lake City 4	860 West 17th South Street
Cleveland 15	2262 Guildhall Building	San Francisco 11	1583-200 Bush Street
Detroit 26	1551 Lafayette Building	Seattle 1	1350 Henry Building
Havana	402 Abreu Building	Tulsa 3	1646 Hunt Building
Houston 2	2115 National Standard Building	Washington 6, D.C.	1109 Cafritz Building

FUNNY IN THE CIRCUS...

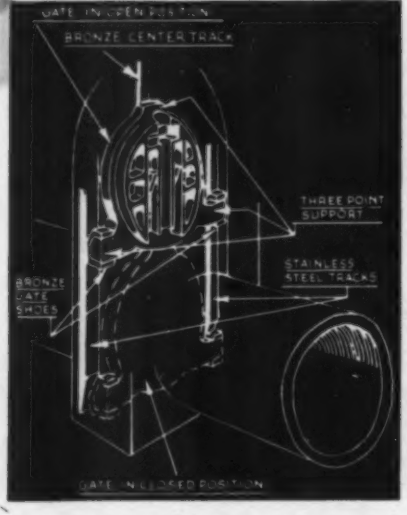


but not in a VALVE GATE

In an ordinary gate valve, when in a partly open position, flow of water constantly causes the downstream gate to *tilt* into the downstream port opening. That means the gate face gouges the valve seat, causing scarring and leakage.

But in the Rensselaer Square Bottom Gate Valve, the gate *cannot tilt.* It runs on tracks all the way. It is held steady and clear of the valve seat by *three point support* right to the moment of closing. The diagram shows why the Rensselaer Valve Gate never touches the seat except in fully closed position — hence doesn't scar or scuff it, and remains tight through long years of service. Ideal for emergency shutoff, frequent operation, throttling, and vertical pipe lines.

Call your experienced Rensselaer representative for more data on this and other Rensselaer products.



LEADERSHIP FOR OVER 65 YEARS

RENSSELAER
VALVE COMPANY

Hydrants • Gate Valves • Square Bottom Valves
Check Valves • Tapping Sleeves and Valves • Air Release Valves

TROY, NEW YORK

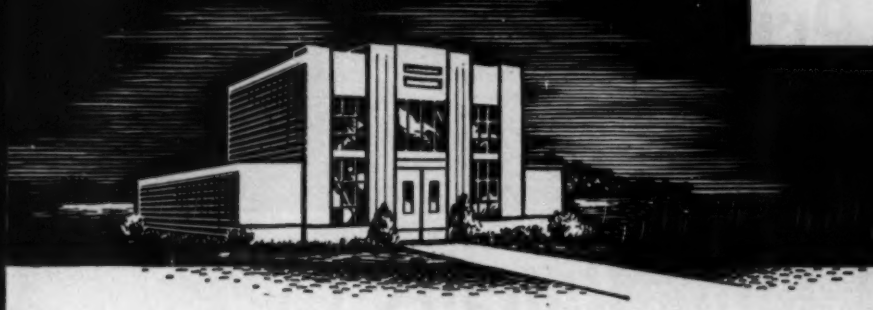
Division of Hoppers Motor Company

Atlanta, Bala-Cynwyd, Pa., Chicago, Denver, Haverhill, Mass., Kansas City, Los Angeles, Memphis, Oklahoma City, Pittsburgh, San Francisco, Seattle, Waco.

Facts

ABOUT FAIRBANKS MORSE DUAL FUEL ENGINES

- Over 160,000 hp. sold—128 engines—more than any other manufacturer.
- Savings reported over 50% in fuel cost.
- Field conversion parts available for many models.
- Basic Fairbanks-Morse design advantages—2 cycle, low rpm, low BMEP, fewer moving parts, proved record of performance.



A Sure Way to Get Lower Cost Kw-h!

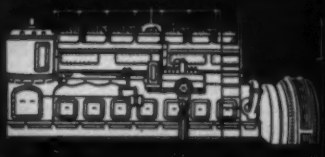
Wherever natural or sewage gas is available, diesel plant operators are producing lower cost kw-h by converting to dual fuel—or installing new dual-fuel engines. Leading the trend in this relatively new diesel development is Fairbanks-Morse, with field conversion parts for many popular sizes of Fairbanks-Morse diesels—and with a growing line of factory-built dual-fuel engines.* If you haven't thought of the savings dual fuel operation can bring to your plant—*you should. When you do, think of Fairbanks-Morse, for no other manufacturer has equal experience in building, installing and servicing dual-fuel engines!* The benefits of this experience are yours for the asking. Fairbanks, Morse & Co., Chicago 5, Illinois.

*Write for information, stating size and type of engine in which you are interested.

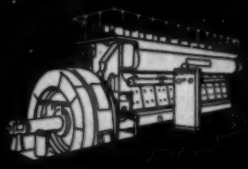
FAIRBANKS-MORSE,

a name worth remembering

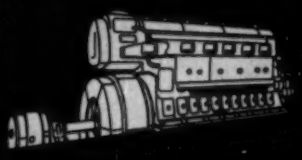
DIESEL AND DUAL-FUEL ENGINES • ELECTRICAL MACHINERY • PUMPS • SCALES • DIESEL LOCOMOTIVES • HOMEWATER SERVICE EQUIPMENT • FARM MACHINERY



Model 31. Up to 3500 hp.



Model 33. Up to 2000 hp.



Model 38. Up to 2000 hp. (Opposed-Piston type)

1	Locating Leak
2	Breaking Through Pavement
3	Digging Bell Hole
4	Keeping Bell Hole Dry
5	Cleaning, Preparing Joint
6	**Purchase Price of Clamp**
7	Making Repairs
8	Backfilling
9	Repaving

What Price Permanence in Bell-Joint Repairs?

SO VERY SMALL is the cost of a Dresser Style 60 Clamp, compared to the total cost of a repair, that it makes permanence an outstanding bargain.

That's why so many cities make it standard practice to clamp bell-and-spigot joints whenever they are uncovered for *any* reason. Once installed, the Dresser Style 60 Clamp absorbs the vibration or movement that caused the leak. Eliminates the risk of losing your investment of time and labor due to failure of patchwork repair methods.

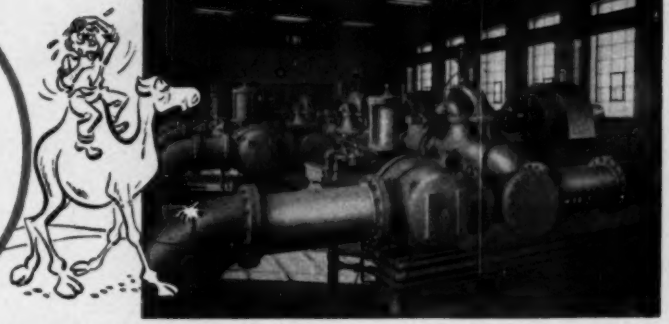
Whenever leaks occur in a bell-and-spigot line, whenever a joint is uncovered, whenever street paving is planned, whenever lines are subject to movement or vibration—"fix it once . . . fix it for good" with Dresser Style 60 Clamps.

Dresser Style 60's come in sizes from 3" to 60", and are fully adjustable for tight fit on all classes of pipe. Write today for literature and prices.

DRESSER BELL-JOINT CLAMPS

Dresser Manufacturing Division, 59 Fisher Ave., Bradford, Pa. (One of the Dresser Industries) · In Texas: 1121 Rothwell St., Houston · In Canada: 629 Adelaide St., W., Toronto, Ont. · Sales Offices: New York, Philadelphia, Chicago, Houston, San Francisco.

De Laval products at work!



80 miles from lake to faucet!

That's a long way to go for a drink of water, but for the cities of Saginaw and Midland, Michigan, Lake Huron was the closest source of potable water in adequate quantity. Four De Laval pumping units handling a total of 70 MGD against 300 ft. head at the lake, and four more at a pumping station half-way between Saginaw and Midland do the entire job.

Whether you want to pump something 80 miles, 80 feet, or 80 inches, give us a call.

Pittsburgh "flood-proofs" it's water supply!

This new 100 million gallon per day De Laval pump for Pittsburgh is supposed to run under water once in a while. By mounting the motor on a platform above the highest flood stage ever reached by the Allegheny River, Pittsburgh is assured of an adequate water supply even in flood times. *You may never want to run a pump under water, but you can bet our engineers will have the right answer to your problem.* Give us a call next time.

DE LAVAL STEAM TURBINE CO., TRENTON 2, N. J.

TURBINES • HELICAL GEARS • CENTRIFUGAL BLOWERS AND COMPRESSORS
CENTRIFUGAL PUMPS • WORM GEAR SPEED REDUCERS • IMO OIL PUMPS

50th DE LAVAL Anniversary

The water main that never grows old—

"Century"® ASBESTOS-CEMENT PIPE!

Original installation of "Century" Pipe previous to relaying it at the new lower grade.

Engineers: Tighe and Bond, Holyoke, Mass.
Contractors: Scott Bros., Ludlow, Mass.

CONSIDER the experience of water department officials in South Hadley Falls, Mass.: In 1950, it was decided to add three miles to the existing system of "Century" Pipe. At the same time, it was necessary to relocate several hundred feet of the original pipe to make it conform to the grading plans for a new development area. But, because "Century" Pipe never grows "old," there were no difficulties involved: A trench was dug to the new grade paralleling the original pipe run, and the same "Century" Pipe, with *the same Simplex Couplings was relaid and reused at the new level!*

The high re-use value is just one example of the continuing economies of "Century" Asbestos-Cement Pipe—economies that start with the low cost of the pipe. "Century" Pipe, though exceptionally strong, is light in weight—is economical to ship and store; can be handled easily and laid quickly. It can be cut and tapped in the field. And, because "Century" Pipe never tuberculates and will not rust or corrode, its original carrying capacity never decreases; it does not increase pumping costs; the pipe is always efficient, always "new"!

Before you buy or specify any pipe for water mains, get the complete story on K&M "Century" Asbestos-Cement Pipe. We'll gladly send details upon request.

Nature made Asbestos . . .
Keasbey & Mattison has made it serve mankind since 1873

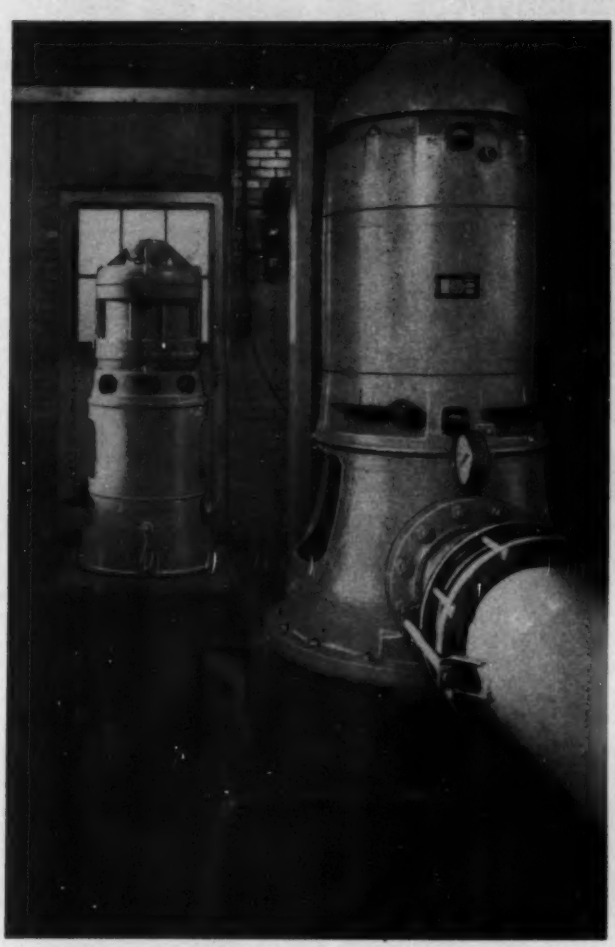
K&M Asbestos Rope for yarning bell and spigot joints reduces the hazard of high bacterial content following the laying of water mains. Write for details.

KEASBEY & MATTISON®
COMPANY • AMBLER • PENNSYLVANIA

See us at Booths 35 and 36, American Water Works Association Convention, Miami, Florida, April 29-May 4, 1951

BEATRICE, NEBRASKA UPS WATER SUPPLY

WITH A LAYNE SHORT SETTING BOOSTER PUMP



The above Layne Well Unit (in background), driven by a 60 H.P. solid shaft motor, was installed in 1931 and has been operating efficiently for almost twenty years.

FROM four Layne Well Water Units, Beatrice, Nebraska was putting 1600 gallons of water per minute into the city through their six miles of 14 inch mains. Growth of population and new industries created a need for more. The problem was easily, quickly and economically solved by installing a Layne Short Setting Booster Pump in line with the wells. As a result, water supply was increased to 2,380 gallons per minute—nearly 41 percent.

The Layne 2-stage, 15 inch bowl booster pump, powered with a 100 H.P. motor was easily accommodated in a small pump house addition, thus saving the cost of extra heating equipment. Installed in 1948, it is giving highly satisfactory service.

These Layne Short Setting booster pumps may be used by other cities—and factories as a means of increasing water supply at a very nominal cost.

If you are in need of more water either from your present wells, or from new units, Layne engineers will gladly survey your present equipment and make dependable recommendations. For further information, catalogs, etc., address

LAYNE & BOWLER, INC.
General Offices, Memphis 8, Tenn.

Layne
WELL WATER SYSTEMS
VERTICAL *Turbine* PUMPS

LAYNE ASSOCIATED COMPANIES

ASSOCIATED COMPANIES—Layne-Arkansas Co., Stuttgart, Ark. ★ Layne-Atlantic Co., Norfolk, Va. ★ Layne-Central Co., Memphis, Tenn. ★ Layne-Northern Co., Mishawaka, Ind. ★ Layne-Louisiana Co., Lake Charles, La. ★ Louisiana Well Co., Monroe, La. ★ Layne-New York Co., New York City ★ Layne-Northwest Co., Milwaukee, Wis. ★ Layne-Ohio Co., Columbus, Ohio ★ Layne-Pacific, Inc., Seattle, Wash. ★ The Layne-Texas Co., Ltd., Houston, Tex. ★ Layne-Western Co., Kansas City, Mo. ★ Layne-Minnesota Co., Minneapolis, Minn. ★ International Water Corp., Pittsburgh, Pa. ★ International Water Supply, Ltd., London, Ont. ★ Layne-Hispano Americana, S.A., Mexico, D. F. ★ General Filter Company, Ames, Iowa.

ACT NOW!

rehabilitate your water system and give it new life with . . .

IOWA

MECHANICAL JOINT CUTTING-IN VALVES AND SLEEVES

Replace those "tired," worn-out valves . . . be prepared for all emergencies!

Now, more than ever, it's vital to keep your customers supplied with water and fire protection at all times . . . Replace worn-out valves and add needed valves with IOWA Mechanical Joint Cutting-In Valves and Sleeves . . . It's the fastest, simplest and most economical method of cutting gate valves into existing water lines . . . Furnished complete with joint accessories . . . No lead, no jute, no caulking . . . Just a ratchet wrench . . . Ideal as auxiliary valves for fire hydrants . . . Simplifies hydrant inspection and maintenance . . . Act now before it's too late . . . Write today for descriptive literature!

KEEP WORK CREWS BUSY ON JOBS LIKE THIS . . . IT PAYS!

IOWA VALVE COMPANY

201-299 N. Talman Ave., Chicago 80, Ill. • *A Subsidiary of James B. Clow & Sons*

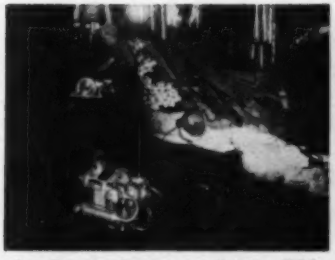
Ready for emergencies—any emergency

HOMELITE

Carryable

PUMPS GENERATORS and CHAIN SAWS

No matter what the emergency . . . a storm, a flood or anything else . . . you'll need, as history has proved, Homelite Carryable Pumps, Generators and Chain Saws. Fully mobile, easily carried by one man, these gasoline-engine-driven units, give you a highly flexible means of repairing damage and restoring safety in the fastest possible time.



For all types of emergency lighting. With Homelite Carryable Gasoline-Engine-Driven Generators, you can operate brilliant floodlighting for urgent night repairs. You can supply power to restore telephone or other communications paralyzed through loss of normal power. You can supply electricity for hospitals, relief centers, or other urgent requirements until normal power is restored.

For flooded buildings or fighting fires. Homelite Carryable Pumps can be rushed to any flooded area, to pump out cellars fast. Each pump handles up to 15,000 gallons per hour. Pumps water thick with debris without clogging. Can be used also for fighting isolated fires, with water pumped from nearby wells, brooks, rivers or ponds.

For cleaning up the damage. Every disaster leaves a trail of damage. Fast clearing of this damage is essential . . . to rescue lives and to facilitate repairs. Have Homelite Gasoline-Engine-Driven or Electric High Cycle Chain Saws handy for this work. With one of these saws, one man can do more work than two men . . . *and much faster.*

CARRYABLE

PUMPS • GENERATORS • BLOWERS • CHAIN SAWS

PERFORMANCE · DEPENDABILITY · SERVICE

HOMELITE

CORPORATION

704 RIVERDALE AVENUE • PORT CHESTER, N. Y.

It costs more to fix piping now!

No. 1615 Diaphragm Valve Iron Body, Neoprene lined

You do less fixing by using Dependable Quality

CRANE VALVES

...That's why more Crane Valves are used than any other make

better performing diaphragm valves

Separate disc and diaphragm design distinguishes these Crane Valves from all similar packless types. Life of diaphragm is multiplied because it's used only to seal the bonnet—not for seating. The separate disc seats the valve, eliminating wear and tear on the diaphragm.

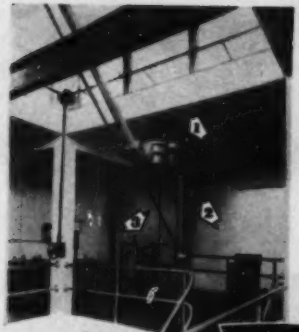
Increased flow capacity... reduced flow resistance... tighter seating... lower torque and fewer turns to operate... are typical added features of Crane Diaphragm Valves. Wherever you use them, you can be sure of outstanding performance.

Such better quality and greater dependability mark Crane valves and fittings of every type—and assure the lowest ultimate cost.

CRANE

CRANE CO., *General Offices:*
836 S. Michigan Ave., Chicago 5, Ill.
Branches and Wholesalers Serving All Industrial Areas

VALVES • FITTINGS • PIPE • PLUMBING • HEATING



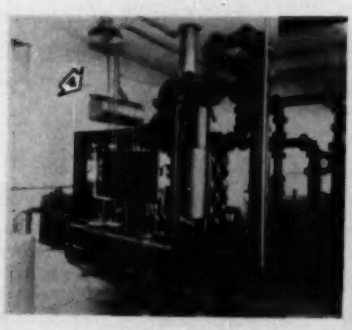
THE LAST WORD IN SEWAGE TREATMENT AT CHARLOTTE, N.C.*

* WITH

P.F.T.

the last word in sewage treatment equipment

At Charlotte, N. C., both the Irwin Creek plant and Sugar Creek plant, built in 1903, consisting of sedimentation and contact filters, were modernized in 1928, by conversion to activated sludge plants. In 1950 the Irwin Creek plant underwent a second stage of modernization and enlargement embodying P.F.T. Floating Covers, (1) Gas Safety Equipment, (2) Cover Position Indicators, Supernatant Selectors, and (3) Sight Glass Control Gauges and (4) Digester Heaters and Heat Exchangers. Activated sludge portion of this plant was extended and redesigned to incorporate the P.F.T. Kraus Process. Plans are underway to similarly enlarge the Sugar Creek plant. These projects are under direction of J. N. Peace & Co., Consulting Engineers, Charlotte, N. C.



P.F.T.

PACIFIC FLUSH TANK CO.

Waste Treatment Equipment Exclusively Since 1893

4241 RAVENSWOOD AVE. CHICAGO 13, ILLINOIS

NEW YORK • LOS ANGELES • SAN FRANCISCO • CHARLOTTE, N. C. • JACKSONVILLE • DENVER

Saved!

...Hundreds of Man-Hours on New Installations

YOU

CAN NOW DO AN ALL MECHANICAL-JOINT JOB WITH PIPE, FITTINGS, VALVES AND HYDRANTS

...with EDDY Mechanical-Joint Valves

After excavation, two unskilled workmen and a ratchet wrench can install Eddy Mechanical-Joint Valves in a jiffy. This can mean many man-hours saved each year. What's more, the work can be done in a flooded trench, or in any kind of weather—for no caulking, no lead-melting is needed . . . and all joints are *bottle-tight* under pressure. Valves meet AWWA specifications, and are available in sizes 3" to 12" for use on both sand-cast and centrifugally-cast iron water pipe.

...and EDDY Mechanical-Joint Fire Hydrants

Since 1849 EDDY For Long Service

Mechanical-Joint connection allows quick, easy installation or removal (with or without auxiliary valve). Hydrants also available with bell or flanged connection. All operating parts accessible by removing top cover. Hydrants open fast, close easily. Even a bent stem does not cause water loss, and drip-action prevents freeze-up. Stock up now on both Clow Mechanical-Joint Cutting-in Valves and Hydrants. Be ready to make easy, speedy installations when needed!

EDDY VALVE COMPANY

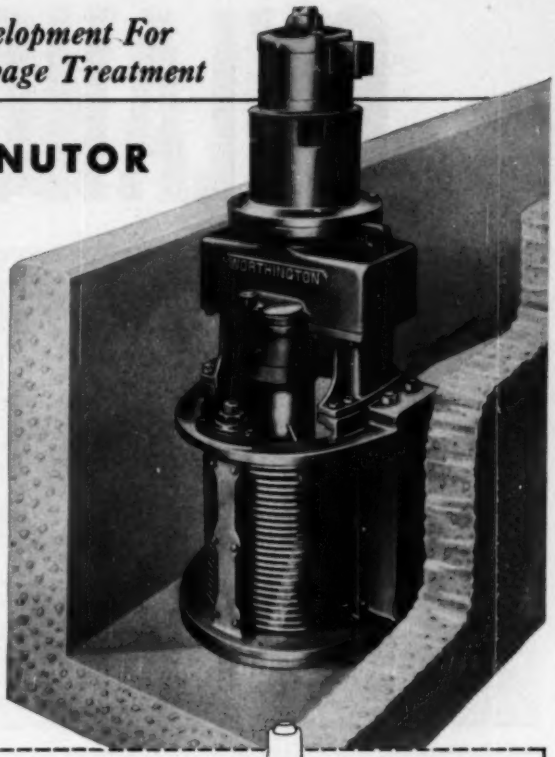
WATERFORD NEW YORK

A Subsidiary of James B. Clow & Sons

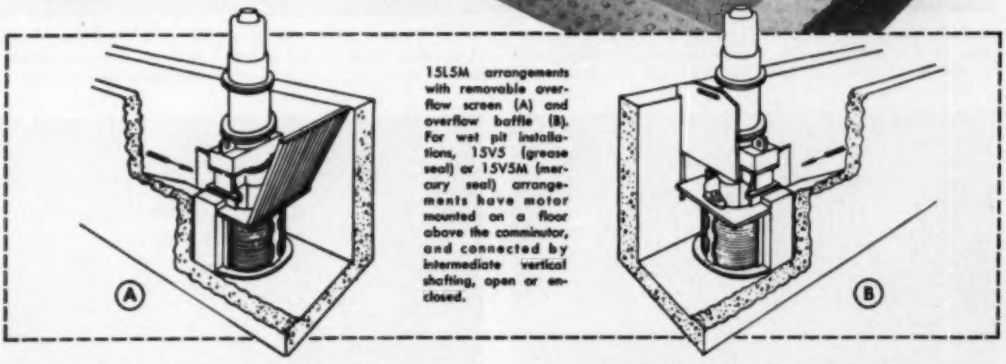
Another Worthington Development For Time- and Labor-Saving Sewage Treatment

THE ONLY COMMINUTOR WITH ALL THESE ADVANTAGES...

- **Easy installation in straight-flow rectangular sewage channels, new or old.**
- **Cutter racks quickly removable for sharpening or replacement, eliminating tedious individual cutter sharpening and adjusting.**
- **Provision for a mercury seal, for automatic protection of internal parts at unusually deep submergences. (Grease seal furnished as standard equipment.)**
- **Provision for overflow screen or baffle by means of a supporting flange.**



The 15C5 Worthington comminutor arrangement for continuous, automatic sewage solids cutting. This unit is designed for a .3 to 2.3 mgd flow range in a channel of 3 feet maximum depth. Standard grease seal supplied is suitable for water depths up to 22 inches. ➔



15L5M arrangements with removable overflow screen (A) and overflow baffle (B). For wet pit installations, 15V5 (grease seal) or 15V5M (mercury seal) arrangements have motor mounted on a floor above the comminutor, and connected by intermediate vertical shafting, open or enclosed.

In many installations infiltration subjects comminutors to peak flows and submergences beyond their maximum capacities. Only Worthington comminutors can be supplied with both a mercury seal and an overflow screen or baffle to handle this problem.

The mercury seal automatically protects the unit's internal parts up to a reasonable submergence. The gear head motor is mounted on a motor base extension pipe above high water level; channel depth may be over 3 feet. The removable overflow screen provides screening at the comminutor's overflow without causing troublesome upstream conditions, and occasional accumulations may be raked down into the unit. Or, an overflow baffle may be used to back the sewage up through the by-pass screen, preventing overflow.

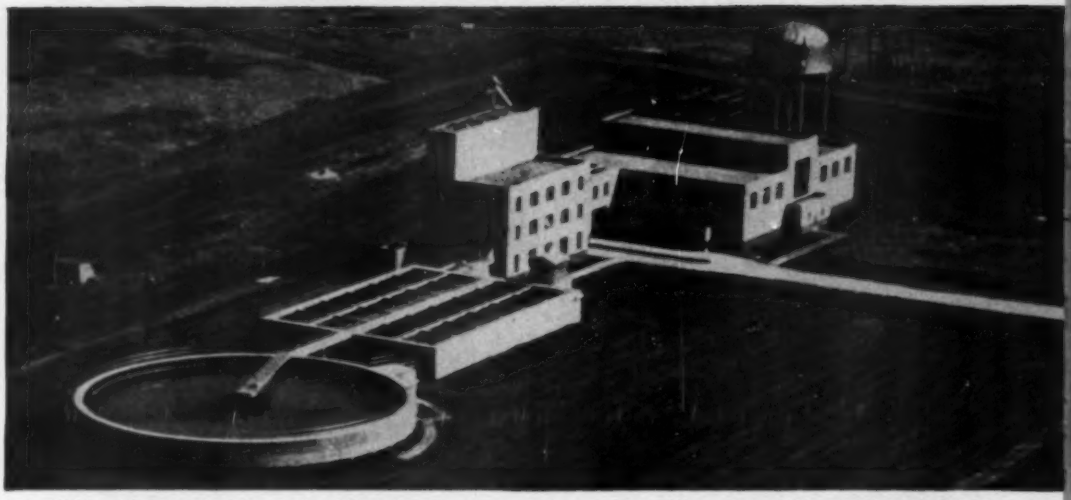
Many Other Advantages

of the Worthington comminutor combine for rapid, continuous, automatic comminution — and for the long, trouble-free service life that proves *there's more worth in Worthington*. Write for bulletin W-2010-B3, and for drawings of arrangements best suited to your own application. Or contact our nearest District Office. *Worthington Pump and Machinery Corporation, Harrison, N. J.*

WORTHINGTON

W-2-0

OKLAHOMA CITY



Lake Heffner filtration plant is rated at 15 mgd, and consists of a circular clarifier, flocculator, final settling tank, carbonator, chemical building, filtration building, and wash-water tank. Water flows 4½ miles from the North Canadian River to the plant. Treatment provides water that is as nearly ideal as is commercially practicable.

Unit substation on balcony in filter house includes economical factory-assembled G-E Cabinetrol* panels. This equipment transforms incoming power and safely controls the low-head, induction-motor-driven centrifugal pumps. Note space-saving location.

All pumps in the plant are controlled from this G-E 2400-volt, metal-clad switchgear. This compact assembly, factory-built and shipped as a unit for economical installation, provides maximum protection of personnel.

*Reg. Trade-mark of General Electric Company

GENERAL ELECTRIC

666-60

ACTS NOW... FOR MORE WATER TOMORROW

New Filtration Plant, Powered by G-E Equipment Assures 4-year Storage Supply

Far-sighted planning by municipal officials of Oklahoma City has resulted in the addition of the Lake Heffner Filtration plant to the city's water system. Now this progressive city need have no fear of its water supply running short for many years to come. Between the new installation and the previously existing Lake Overholser plant, there is a combined surface storage that represents about a four-year supply of water at the present rate of consumption.

To help assure dependable operation of the pumps in the Lake Heffner plant, General Electric motors, control, power-distribution and switching equipment were selected. This assurance of dependability is based on the fact that General Electric has been furnishing drives, power-distribution systems and process controls for water plants, and numerous other industries, for many years. Out of this rich background of experience has come the co-ordinated G-E water-plant equipment, notable for its reliability.

General Electric can help you, your consulting and city engineers, and your contractors in developing the electrical system for your water supply. The best time to use this help is in the planning stage of your modernization program. A call to your G-E representative at this time will go a long way toward making your water-supply program a success. *Apparatus Dept., General Electric Co., Schenectady 5, N. Y.*

The 2-mgd wash-water centrifugal pump, right, is powered by a G-E Tri-Clad* 2300-volt, 40-hp motor. Left rear, are two 5-mgd distribution-system centrifugal pumps driven by G-E 2300-volt, 300-hp synchronous motors.

This section of the pump room on the ground floor of the filter building shows a G-E 2300-volt, 600-hp, 1200-rpm synchronous motor that drives the 10-mgd distribution-system centrifugal pump in the background.

GE CO-ORDINATED WATER-PLANT ELECTRIFICATION

formed under vacuum for greater strength

Vitrified CLAY PIPE

DE-AIRING — a process that makes Clay Pipe *stronger* for greater load-bearing, *denser* for less absorption, and dimensionally *truer* for faster installation — takes place in a vacuum press as the pipe is precision-formed under pressures as high as 75 tons.

De-airing, like the exclusive Vitrification process, is an outstanding example of technology at work for you . . . bringing you *better* Clay Pipe — stronger, denser, truer lengths for every sewerage and drainage use. Industry-wide research is constantly improving the traditionally high quality of Vitrified Clay Pipe — and developing new test procedures to *insure* consistent standards.

Vitrified Clay Pipe requires no "extras" . . . no special coatings to protect it from deterioration. It is corrosion-proof *throughout* — completely immune to destructive chemicals in soil, sewage, or industrial waste. You can specify it *safely*, with complete assurance that Clay Pipe *never wears out*.

NATIONAL CLAY PIPE MANUFACTURERS, INC.
100 N. LaSalle St., Rm. 2100, Chicago 2, Ill.
206 Connally Bldg., Atlanta 3, Ga.
703 Ninth & Hill Bldg., Los Angeles 15, Calif.
311 High Long Bldg., 5 E. Long St., Columbus 15, Ohio

SPECIFY *Vitrified* CLAY PIPE

WRITE FOR DETAILED INFORMATION

Additional information and data on Vitrified Clay Pipe, Wall Coping and Clay Flue Lining sent FREE on request. State your specific questions. Simply contact the regional office nearest you.

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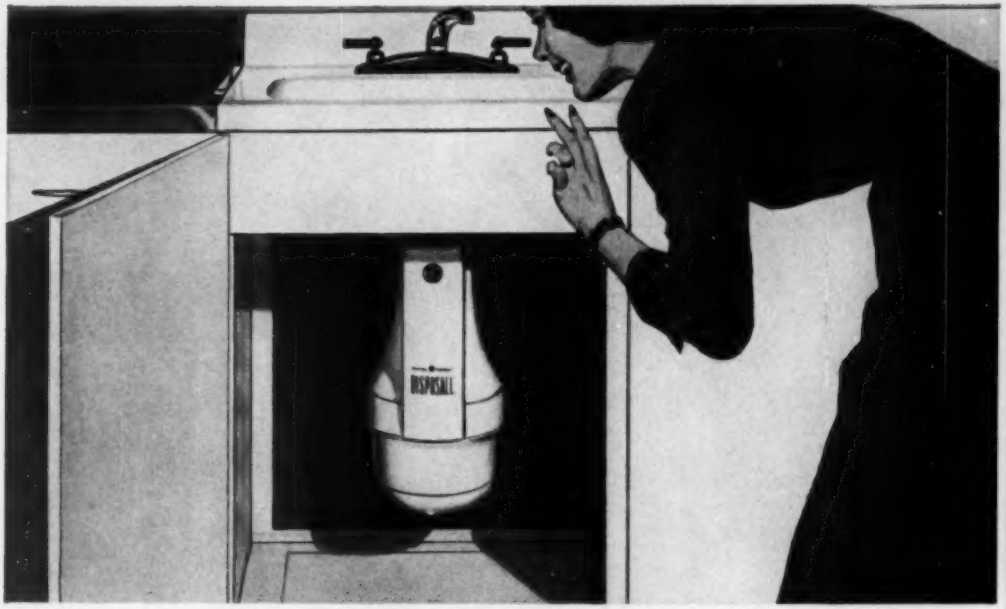


Opening the door for a friend of the community!

Meet the latest, greatest friend of housewives—of sanitary officials—of communities everywhere.

Meet the sure, powerful enemy of garbage—of the filth and disease that garbage breeds.

Greet the new, compact, efficient General Electric Disposall®—designed to fit practically every sink . . . built for years and years of dependable operation!

There's everything new and better about this food-waste shredder—from the all-white, kitchen-bright exterior—to the smallest working part. The shredder and rotating impellers, made of one of the toughest alloys known, will really grind food waste—from rubbery fruit skins to the most stubborn beef bones.

G-E engineers have added safety factors—including the strength to prevent mechanical breakdown if foreign objects of glass or metal should be dropped in accidentally with food wastes.

There's built-in economy, too! For, on a yearly average, this G-E Disposall will use less electricity than an electric clock—will use less water than is now required to clean sinks, sink strainers and to flush out garbage containers. And, because it is built and designed for a long life with little or no maintenance, the actual owning cost of a Disposall has been found to average as little as 10¢ per unit per year.

First, last and always, though, the Disposall means SANITARY PROTECTION. It shreds food wastes to small, uniformly sized particles and discharges them at an even rate—in the combination found best through 15 years of G-E experimentation. And these particles are washed away in water with a scouring action that keeps traps and pipes whistle-clean.

Whether wastes are disposed of through sewer or septic tank, the G-E Disposall preserves the full benefits of the sanitary plumbing system—all the way from sink to sewage treatment plant!

Truly, there is no food-waste shredder that can match the new G-E Disposall in design, in performance, in dependability.

As guardian of the community, of its health, safety and economy, you will surely want to open the door for a great friend of the community—the new G-E Disposall!

New, streamlined G-E Disposall is available in two models. Quick, easy installation can be made in practically every sink. For further information about the Disposall method, simply write to Department WSW 451, General Electric Co., Bridgeport 2, Conn.

G-E DISPOSALL

You can put your confidence in—

GENERAL ELECTRIC

THRESHOLD TREATMENT WITH calgon*

CONTROLS CORROSION . . . PREVENTS LIME SCALE . . . STABILIZES DISSOLVED IRON AND MANGANESE . . . STABILIZES WATER FOLLOWING SOFTENING

The simplicity and economy of *Calgon Threshold Treatment* together with its great effectiveness in solving many of the most serious problems commonly encountered with municipal and industrial waters has made it a standard method of treatment.

Hundreds of major supply systems in all parts of the world find it profitable to use Calgon regularly for one or more of these purposes.

We will be glad to discuss your problems and tell you exactly what Calgon can accomplish in your situation.

*T. M. Reg. U. S. Pat. Off.

Be sure to visit booths No. 85-86 at the A.W.W.A. Convention in Miami, April 29 to May 4.

CALGON, INC.

HAGAN BUILDING
PITTSBURGH 30, PA.

"My Men Quit Fighting Quicksand The Day We Got Our Hydrocrane"

Says Water Department Superintendent

Easy digs it as the department's crane excavates on a Water Department job.

Every work function fully hydraulic—boom and load hoist, swing, boom telescope, outrigger action and bucket close.

"Quicksand and cave-ins made leak repairing the most unpopular work in the department," says Jerome C. Zufelt, Sheboygan, Wis., Water Department Superintendent. "Now with our Hydrocrane doing the digging the boys don't mind this job at all."

Faster Repairs Mean Better Public Relations—Zufelt pointed out that using the Hydrocrane benefits the public, too. With this rig speeding leak repairs, shut-off periods are shortened as much as 50%. He remembered being called out to inspect a leak repair job one Sunday afternoon. Before he could get there, the entire job had been completed. The leak was uncovered, repaired and backfilled in 90 minutes — with hand labor this job would have taken at least four hours.

Busy on Other Jobs Too—The crane is also used for laying pipe. On one job of laying 2,000 ft. of 12-in. water main, Zufelt observed, "We set 200 ft. per day but the crane could have handled 600 ft. a day if the trench had been ready. The pipe crew set pipe as fast as the trencher moved." The department also uses the crane for placing hydrants and valves, transferring pipe from gondola cars to trailers, and for miscellaneous jobs around the yard.

Both the ¼-yd. 2-ton and ⅜-yd. 3-ton Hydrocranes are winning new friends among municipal and public works users everywhere. Owners like the variety of attachments—clamshell, crane hook, grapple, magnet, bulk materials bucket and catch basin cleaner.

Bucyrus-Erie Hydrocrane Division
South Milwaukee, Wisconsin

BUCYRUS-ERIE HYDROCRANE DIVISION
South Milwaukee, Wisconsin

Gentlemen: Please send Hydrocrane bulletins to:

Name.....

Company.....

Address.....

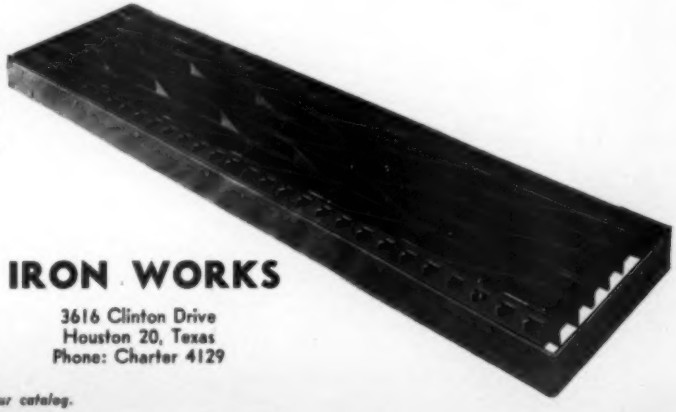
City.....State.....

104HB1

Arrowhead Grating is made to fit the job, eliminating the waste and expense of field cutting. All pieces are punched and bolts furnished to make a one piece floor or walkway when installed.

Arrowhead Grating is comfortable and quiet to walk and work upon since the pattern provides bars extending in every direction.

Arrowhead Treads are designed to include a definite slip proof nosing that will not become distorted even under extremely heavy use.



ARROWHEAD IRON WORKS

1010 Gentry
North Kansas City 16, Mo.
Phone NOrclay 3121

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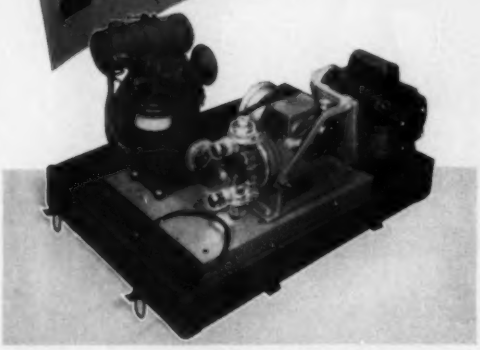
Houston 20, Texas
Phone: Charter 4129

Write for our catalog.

EMERGENCY WATER TREATMENT *for* CIVILIAN DEFENSE



Dual drive (electric and gasoline) Chlor-O-Feeder
— an ideal standby unit for emergency chlorination service or main sterilization. A constant rate feeder for applying hypochlorite solutions at rates up to 5.5 GPH, pressures to 85 psi.

Hydraulically-operated Chem-O-Feeder
— for constant rate or flow-proportional feeding of hypochlorite solutions to establish and maintain any desired chlorine residual in a portion of a system or a pipeline in use.

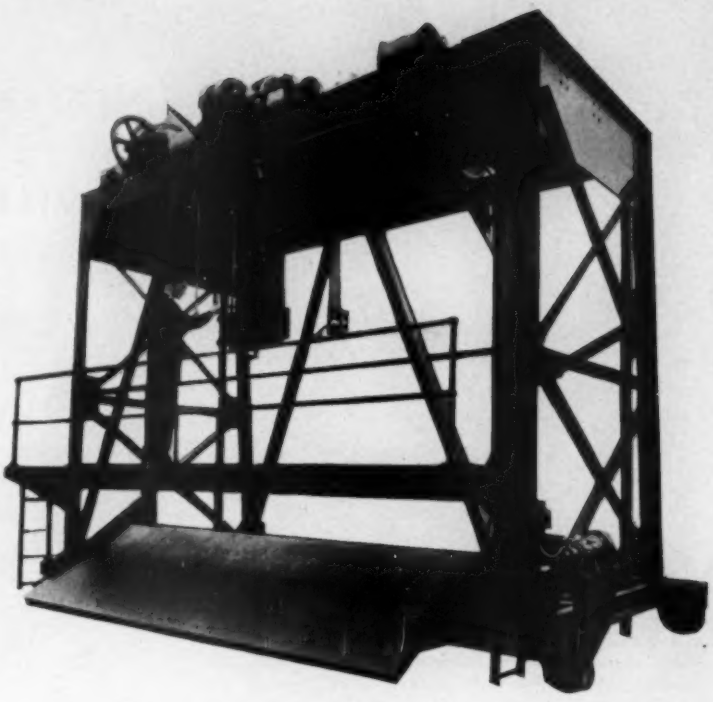
Portable Pumping and Sterilizing Unit
— capable of pumping and hypochlorinating up to 50 GPM of water from any source.

Pur-O-Pumper
— similar to units used by the armed forces. Delivers up to 50 GPM of filtered and chlorinated water. Units of larger capacity available. Light in weight, easily mobile, highly efficient. The Diatomite Pur-O-Pumper removes amoebic dysentery cysts, turbidity, algae, and a large percentage of bacteria.

Make %Proportioneers% your source for emergency sterilization and filtration equipment. Profit by our experience gained in over 33,000 chemical feeding and water purification installations. Write for data and recommendations. %Proportioneers, Inc.%, 350 Harris Ave., Providence 1, R. I.

% PROPORTIONEERS, INC. %

NEWPORT NEWS MECHANICAL RACK RAKE



WATER users troubled with trash are invited to write for new descriptive rack rake catalog.

THE Newport News Mechanical Rack Rake is a power-operated rake for cleaning trash racks at water intakes for hydroelectric plants, steam plants, pumping stations, canals and similar installations. It cleans the rack bars of trash and reduces a former major hand operation to one of minor periodic activity. With Newport News Mechanical Rack Rake installations, one man per shift can, under ordinary conditions, keep the racks clean for a dozen bays.

NEWPORT NEWS SHIPBUILDING AND DRY DOCK COMPANY

NEWPORT NEWS, VIRGINIA

There is a plus value built into every

HAMONDTANK

WATER SPHERE

ELEVATED TOWER

STANDPIPE AND RESERVOIR

February 2, 195-

Dear ----------

You are, no doubt, aware that your erection crew under the direction of ---------- have about completed our standpipe and are preparing to move out their equipment. I, therefore, wish to take this opportunity to let you know that it has been a privilege and a pleasure for me to have associated with such a fine group of men on this project.

It is indeed refreshing in this day and age to find a group of workmen of this calibre and I consider your company fortunate. Without exception, they are extremely hard workers, highly skilled and of exceptional character.

I personally feel they have constructed as good a tank as it is possible to build and I am as proud of the job as the men are.

Very truly yours,

---------- Supt.
------ Water Dept.

✻ *NAME AND DETAILS ON REQUEST*

1,000,000 gallon capacity, 44 feet wide, 89 feet 6 inches high, installation in Connecticut.

100,000 gallon capacity, 100 foot tower installation in Georgia.

100,000 gallon capacity, 100 foot tower installation in Ohio.

100,000 gallon capacity, 50 foot tower installation in Virginia.

HAMMOND IRON WORKS

WARREN, PA. and BRISTOL, PA.

Sales Offices: NEW YORK · AKRON · BOSTON · BUFFALO
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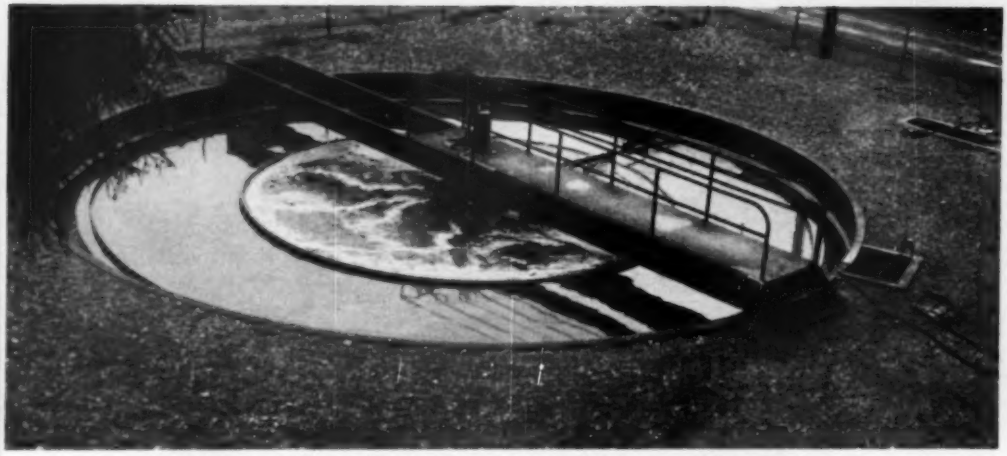
SEASONAL OVERLOAD?

SOLVE WITH

PROCESS OXIDATOR



Process Oxidator at Gilroy, California. R. C. Stockman, consulting Engineer. Stolte, Inc., contractor.

Gilroy, California offers another outstanding example of the flexibility of the Process Oxidator. The facts:

First—the existing primary treatment was augmented by the addition of an aerator ahead of the clarification unit.

Second—a 45' dia. Process Oxidator was installed to operate in parallel.

Both the existing clarifier and the new Oxidator are designed to operate during normal domestic flows as clarification units. During canning season the sewage flow is divided between the preaeration-clarification unit and the Oxidator which combines aeration, coagulation and sedimentation in one tank.

DURING SEASONAL OVERLOADS COMPARATIVE RESULTS HAVE PROVEN THE OXIDATOR WITH ITS SLUDGE RECIRCULATION FEATURE SUPERIOR TO SEPARATE AERATION AND CLARIFICATION. THE OXIDATOR IS PRODUCING AN IMPROVED EFFLUENT ALTHOUGH PROPORTIONATELY RECEIVING A LARGER FLOW.

The unit is also equipped with non-clog air jets.

Send for Bulletin 106 for other examples of this proven sewage treatment process. Or if you have a particular problem, write to either address below and one of our specialized Engineers will be glad to assist you.

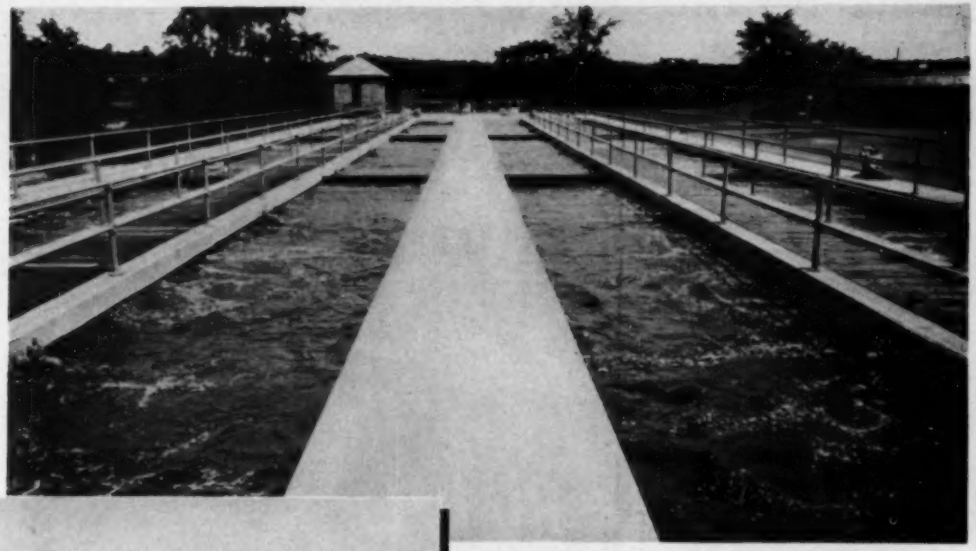
PATENTED AND PATENTS PENDING.

PROCESS ENGINEERS INCORPORATED

212 SUTTER STREET
SAN FRANCISCO 8, CALIF.

6381 HOLLYWOOD BLVD.
LOS ANGELES 28, CALIF.

EASTERN AND MIDDLE WESTERN REPRESENTATIVE:
PACIFIC FLUSH-TANK COMPANY • 4241 RAVENSWOOD AVE., CHICAGO 13, ILL.



ACTIVATED SLUDGE PLANT in New England successfully uses easy-to-clean, long-lasting Norton Alundum* porous plates.

No other porous medium offers you so many advantages as *Fused Alumina*

Norton Alundum (fused alumina) porous mediums for sewage treatment and water filtration are characterized by effective resistance to chemical attack and to abrasion, as well as by great strength and uniform structure.

Chemically Stable!

They are unaffected by acid, neutral and slightly alkaline conditions encountered in these applications. In fact, 30-day immersion tests of Alundum plates in such solutions as 85% phosphoric acid, 96% sulphuric acid, 35% hydrochloric acid, sat. sol. calcium hydroxide showed insignificant cumulative losses.

Exceedingly Strong!

And look at the strength of Norton Alundum plates. Their modulus of rupture, when they are wet, ranges from 1465 psi for a plate with a permeability of *121.0 cu ft/min/sq ft/in. thick* at 2 in. water pressure to 3716 psi for a plate with a permeability of 4.1. So, you can see a Norton Alundum porous plate has sufficient strength for successful application in either sewage treatment or filtration plants.

Highly Refractory!

Because they are fired at high temperatures, Norton Alundum porous mediums resist properly applied temperatures up to 1000° C without any change in physical structure. This gives you the advantage of being able to burn out organic matter if the pores become clogged without endangering the characteristics of the plates.

*Trade-Mark Reg. U. S. Pat. Off. and Foreign Countries

Get All The Facts!

For the complete data on the selection, installation and upkeep of Norton Alundum porous mediums for sewage treatment applications, write for Catalog 1246; for filtration, request Catalog 140. Norton Company, 824 New Bond Street, Worcester 6, Massachusetts.

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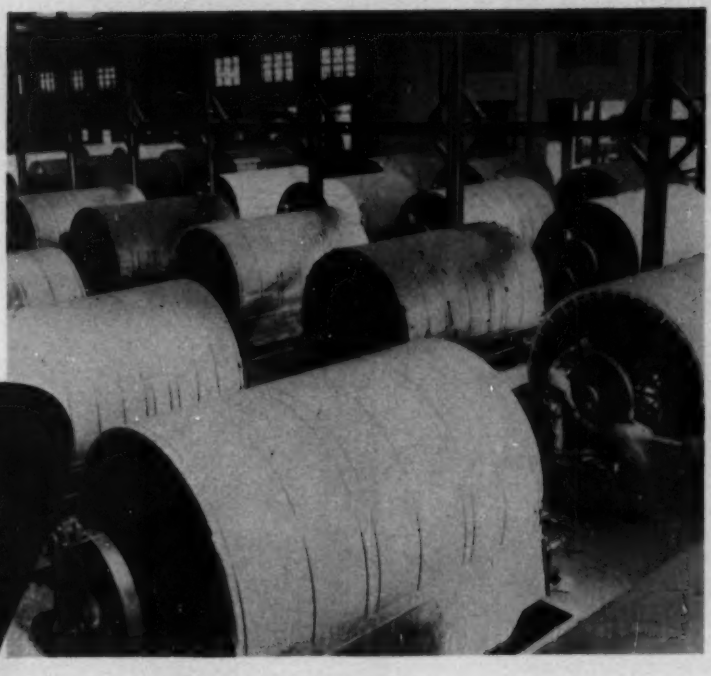

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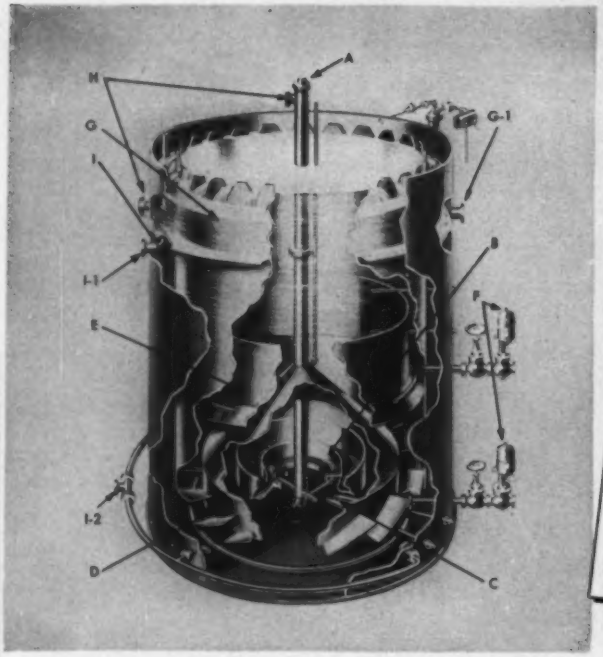

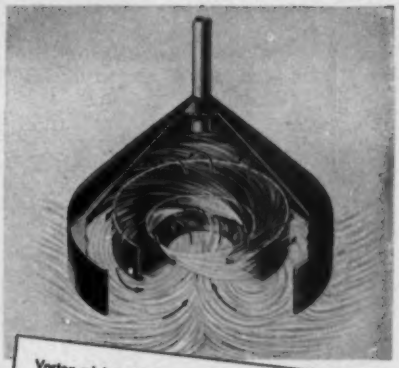

Vortex mixing eliminates need for submerged moving parts in the Worthington Cold Process Slurry Type Precipitation Water Softener and Coagulator.

REACTION TANK of Worthington Slurry Type Softener (Slurry bed eliminated for clarity). (A) Raw water influent line. (B) Vortexor for optimum slurry production. (C) Chemical Applicators. (D) Slurry bed rotator. (E) Symmetrical Slurry concentrator. (F) Proportionate sludge removal. (G) Collector trough for treated water. (G-1) Treated water effluent. (H) Complementary recirculation. (I) Filter wash water compartment. (I-1) Filter wash water suction. (I-2) Filter wash water return.

This slurry bed stays put!

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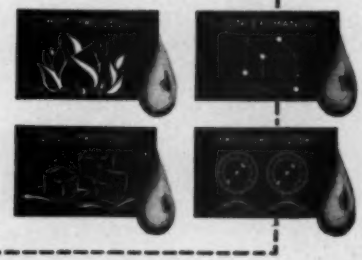
25-1

WORTHINGTON

WATER CONDITIONING

Worthington Makes More of the Equipment for All Types of Water Conditioning Systems



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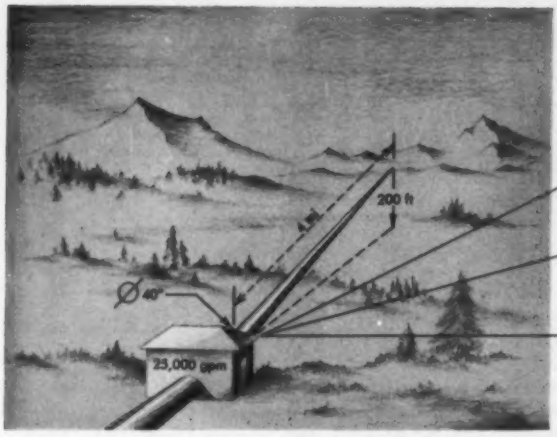

250 feet of head

525 feet of head

975 feet of head

?

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Here is the problem: Estimate how high total pressure head could rise from surge if power failure brought the pump in this system to an abrupt stop.

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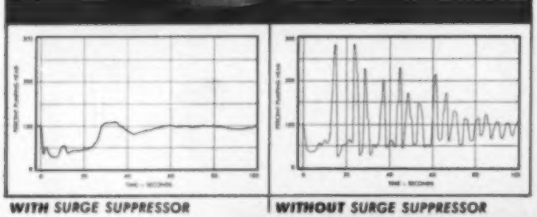
Lower pipeline costs can more than pay for a **PELTON** Surge Suppressor. Extra weight is eliminated because the pipe need not be designed with large safety factors in anticipation of high surge pressures. The possibility of line failures and interrupted service is greatly decreased.

Installations needing protection occur wherever water is pumped to a higher elevation either through a long pipeline or at high velocity. **PELTON** Surge Suppressors can be furnished to protect waterlines of any size handling service pressures up to 800 p.s.i.

Send us ***your*** *problem and include pipeline profile. Our engineers will make recommendations without obligation.*



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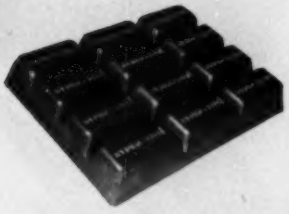

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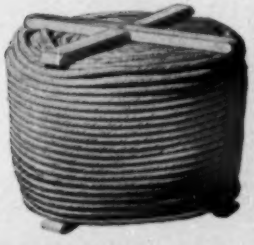

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STATIC WATER LEVEL RECOVERED - 24"

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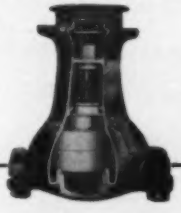

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WATER & SEWAGE WORKS

VOL. 99, NO. 4 • A GILLETTE PUBLICATION • APRIL 1951

Miami's Thrice Enlarged 60 MGD Water Treatment Plant, Hialeah, Fla.

Miami's Hialeah Treatment Plant–1951

With Especial Reference to Experiences with Free Residual Pre-Chlorination at High pH.

by CLARENCE R. HENRY, *Chief Chemist, Dep't. of Water & Sewerage, Miami, Florida.*

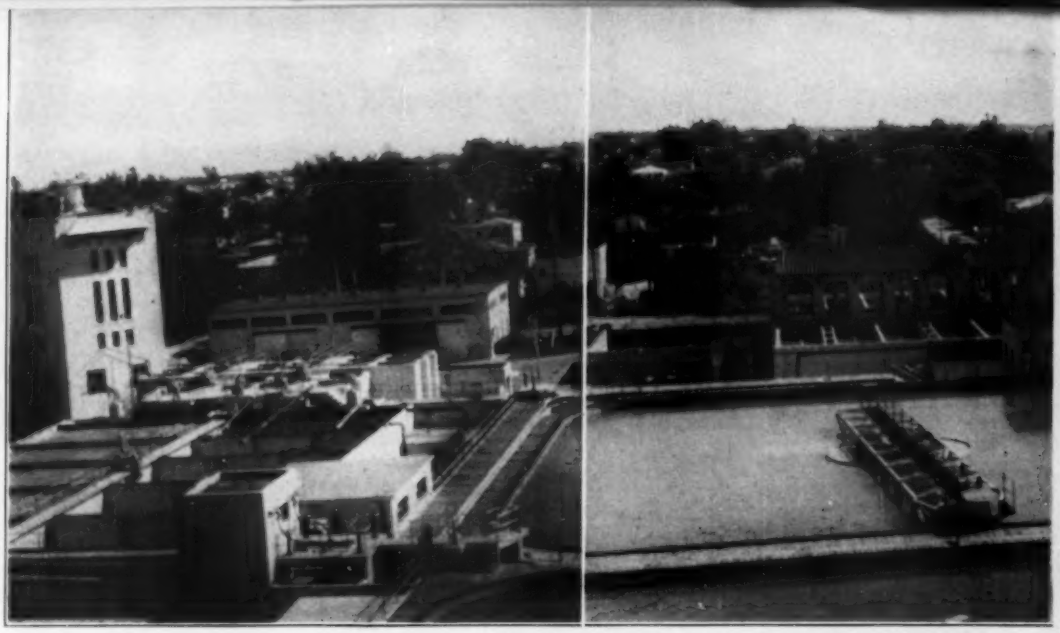
DOWN near the southern tip of the state of Florida, a thin layer of the east coast seems to break off gradually to make the narrow strip that is Miami Beach. It disappears soon after, leaving a few small islands in its wake, to give Biscayne Bay its opening to the sea. It reappears farther south, to form more islands almost touching the mainland, and the series continues, with hundreds of large and small islands clustered along an arc to the southwest, to end somewhere beyond Key West.

The whole state, geologically, is very young. There are no well defined rivers in the southern part, and only a few can barely meander through the low coastal ridge to be lost on touching the edge of the Everglades. The ridge may reach a maximum elevation of fifteen feet above sea level. It is composed of a porous limestone rock, "Miami Oolite". Beginning just north of Miami, 2.5 miles across the Bay from Miami Beach, the ridge follows the coastline for some 30 miles toward the southwest. Although rivers are few, its 5 to 10 miles of breadth is frequently broken by sloughs, the low swampy areas which allow some of the Everglades water to drain toward the ocean during periods of high precipitation.

The Everglades area comprises, roughly, all of the area south of Lake Okeechobee, the largest lake wholy within the continental United States. The exceptions are the coastal ridge along the lower east coast and, farther south, the redlands district near Homestead, and the coastal salt marshes, and the broad Big Cypress Swamp of the west coast. Some idea of the character of this area may be derived from the title

TYPICAL AVERAGE ANALYSIS OF MIAMI WATER

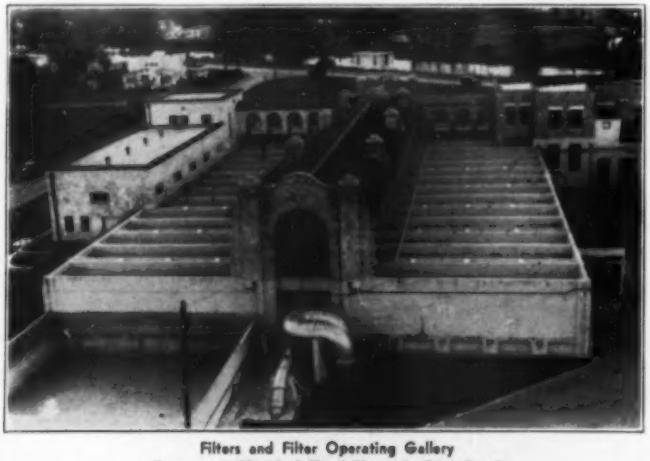
	Well Water	Finished Water
pH	7.25	8.4-8.8
Color	75.	8-12
	PPM	*PPM*
Ammonia Nitrogen (N)	0.5	None
Carbon Dioxide (CO_2)	24.	None
Total Solids	325.	180.
Turbidity	Nil	Nil
Silica (SiO_2)	8.0	8.0
Iron (Fe)	1.5	0.02
Calcium (Ca)	90.	28.
Magnesium (Mg)	7.0	4.0
Sodium & Potassium (Na)	12.	12.
Alkalinity ($CaCO_3$)		
Phenolphthalein	None	5.
Methyl Orange	225.	45.
Sulfates (SO_4)	22.	22.
Chlorides (Cl)	23.	34.
Hardness ($CaCO_3$)		
Total	253.	86.
Non-Carbonate	28.	41.
Chlorine, Free Residual at Plant (Cl$_2$)		0.5-1.0
Fluorides (F)	0.6	0.3



General View, Miami's Water Softening-Filtration Plant from Top of
Refer to Layout and Flow Sketch for identification of Units. Mixing and flocculation basins and Chlorine House on left. Chemical House in left background.

of a recent book, "Everglades, River of Grass" [2]. The whole is underlaid by rock not too different from the Miami Oolite of the coastal ridge. More silica, in the form of sand, is to be found, and, this with very small amounts of iron and magnesium, constitutes the only other additions to an otherwise pure and highly porous limestone rock.

This area is very flat. Lake Okeechobee, some 60 miles northwest of Miami, lies at a mere 9 foot increase in elevation, with 9 evenly spaced 1 foot contours shown on the map. Obviously, heavy rains will flood the Everglades quite rapidly. A long, dry period, coupled with the natural constant loss of water by evaporation and transpiration through vegetation, together with the slow but continuous and voluminous underground flow of water to the sea, results in a rapid drying out of the soil and a lowering of the water table. A system of canals, whose purpose was to drain the Everglades, was begun in 1910. Conditions now are such that locks, dams and levees are under construction to maintain a higher water level in the canals, and thus prevent salt water intrusion from the ocean and bay. The soil of the "Glades", called "muck", is a peat formed largely of decayed sawgrass. After exposure to sun and air, through cultivation, it has shrunk as much as 5 to 8 feet in depth in the comparatively few years since farming has been practiced. During dry weather, the "muck", which overlays all of the true Everglades, will dry out, and partially oxidize. Then, far from the moist, wet, plastic material it once was, the surface of such land will be composed of granules, difficult to wet, which will burn like peat. Also, large cracks develop, which can make walking dangerous. Then, too, with the ground-water level becoming lower year by year, salt water will march up the floors of the rivers and canals and belly inward from the ocean a hundred or two feet underground, through the honey-combed rock.

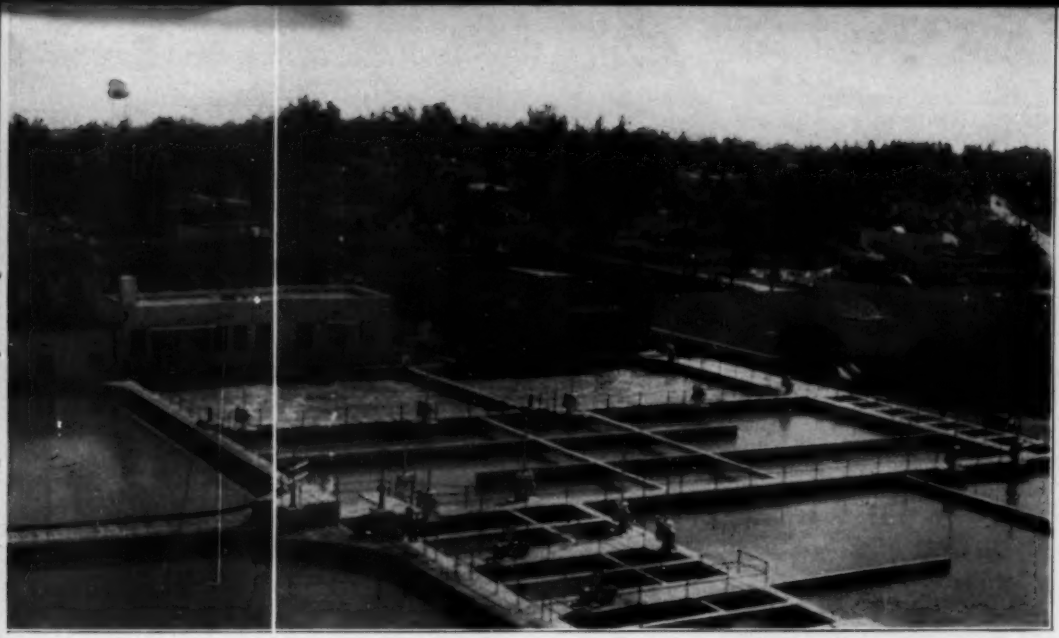


Filters and Filter Operating Gallery
From atop Chemical Head House looking South

Everglades True Source of Supply

The Everglades constitutes the local recharge area, the source of the water supply. Wells sunk to any shallow or moderate depth simply draw on the underground flow of Everglades water enroute to the sea. Attempts to sink deep wells for the purpose of tapping some deeper water bearing strata, develop more and more highly mineralized water.

In the Miami area, a surface is to be avoided for the same reasons which apply elsewhere, because of the rapid variations in both chemical



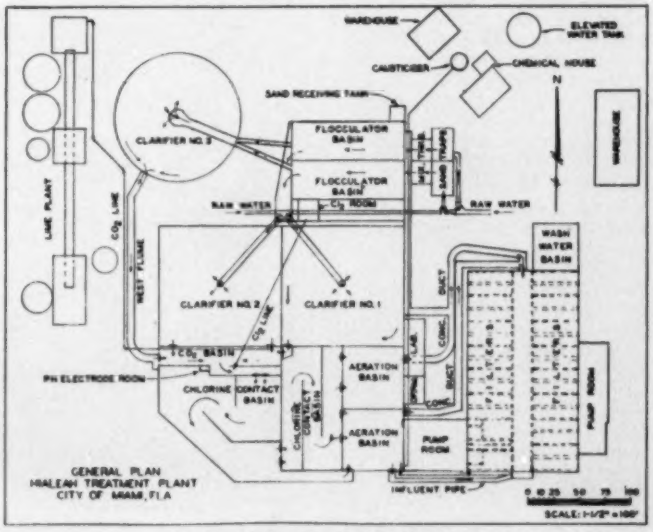
Elevator, and Storage Bin House of Lime Recovery Plant—Looking East.
Clarifiers in center and CO_2 and Chlorine Mixing and Contact Basins on right. Aeration Basins, Filters and Pumping Station beyond.

and bacteriological quality, and the presence of tastes and odors and, in this locality particularly, of high color. Moreover, the surface water is harder to treat, no doubt because of the higher organic load.

The character of the well water is fairly uniform. The composition of water from the Hialeah wells varies from well to well, but composite samples taken over long periods show but little change. A typical average analysis of the raw well water and of the treated water appears in the accompanying table. One advantage of the well water over the Miami Canal water, which flows within little more than a hundred feet of the plant, is the bacteriological quality. It is rare for even one 100 ml portion in five examined to show the presence of the *cali-aerogenes* group in the raw water. The other advantage is it's comparative ease of coagulation, to the extent that no coagulant is required when about 1 gpg excess lime is used in softening. The only obvious divergence in quality from the well water that water from the Miami Canal will show, analytically, is in the alkalinity, which may vary from 150 to 250 ppm and in the color, which is about twice that of the well water. Yet, no amount of alum, up to 137 ppm, will give a settleable floc, regardless of the degree of lime treatment (*). Activated silica is quite effective in any of the local waters at dosages of less than 2 ppm.

The Hialeah Treatment Plant

The Hialeah Treatment Plant is located just north of the Miami Canal about 8 miles northwest of the center of the City of Miami. It was designed in 1924 as a 10 mgd conventional lime softening plant. The capacity was increased to 20 mgd in 1927, then to 40 mgd in 1936, and to 60 mgd in 1946 [13,19]. The greatest water demand occurs during the winter season. Until the latest additions to the quantity of local (distribution) storage at the high pressure pumping stations, and a new 2,000,000 gallon clear well to supplement the old 875,000 gallon clear well, fluctuations in the treatment rate were abrupt and severe.



Layout and Flow Sketch of Hialeah Plant
(See composite photographs above.)

A general plan, revealing the points of chemical application and the flow of water through the present plant, is shown herewith.

The plant is supplied by 22 wells. These are operated in various combinations to meet the water demand. There are four or five 12 inch wells. The rest are 14 inches in diameter. Cased depth is from 54 to 93 feet, and all will deliver about 3.8 mgd, each, at an average draw-down of 5 to 8 feet. Each well has its own motor and pump and discharges into a manifold line to the plant. The temperature of the water is 78°F., and does not change, winter or summer.

The water (see flow plan) first rises in a large sand trap, overflows with slight aeration into troughs leading to the rapid mix tanks and thence into the Dorr Flocculators. Return sludge from the Dorr Clarifiers is added to the water in the overflow troughs to decrease the rate of calcium carbonate encrustation on the walls and baffles, and the lime from the chemical house is added a little later, just before entering the rapid mix tank. After about 12 to 15 minutes of gentle, slow mechanical agitation in the flocculators, the water flows to the 1.5 MG clarifiers for settling. The sludge is removed by pumps operating on cycle and the surplus sludge is sent to the lime recalcining plant.

The lime dosage is 1,580 lbs. MG of 90% CaO, enough to maintain the excess lime treatment in the +10 to +20 range, meaning 10 to 20 ppm hydroxide alkalinity is maintained. As noted, no coagulant is required at this degree of lime treatment. Four baffles divide the flocculator into compartments. Well defined clear water streaks, indicating a readily settleable floc, are frequently seen in the water at the first compartment, which receives the mixing tank discharge.

The two sections of the recarbonating basin receive water from the parallel flow from the clarifiers. Each section contains two American Well Works 3-stage mechanical gas diffusers. A glass electrode measures the pH of the water entering and leaving. This is indicated and recorded in the operators room. The feed of carbon dioxide, (scrubbed stack gas, containing about 20% of CO_2, from the lime recalcination plant) is automatically controlled by means of a "Bristol Free Vane Ampliset," acting on a by-passed valve.

Then, 85 to 90 lbs./MG of chlorine (10 to 11 ppm) is added just

Chemical Head House and Wash Water Tank
(Dust catching equipment on roof.)

beyond this point. The chlorine contact basins provide a minimum of 45 minutes retention prior to aeration. The water flows across the two basins where compressed air is forced through a bottom grid. The water then flows to the 16 rapid sand filters. These are equipped with Palmer Surface Wash mechanism. Chlorine is applied at only one point: there is no post-chlorination.

The finished water is pumped to transmission under about 25 pounds

Typical Well House
Of which there are twenty-two. This one is on the Miami Springs Golf Course.

pressure. Five high pressure pumping stations located throughout the City of Miami increase the pressure to some 70 pounds per square inch. The towns of Hialeah and Miami Springs receive high pressure water direct from the plant. Water for Coral Gables and Miami Beach is purchased from the Department of Water and Sewers of the City of Miami, and distributed through separate distribution systems. The water produced by the Hialeah Treatment Plant (and in the future with the aid of the projected new 80 mgd Southwest Treatment Plant) supplies the whole of the Greater Miami area south of the towns of North Miami and Opa-Locka.

The lime reclamation (recalcination) plant is located just west of the water plant and has a designed production capacity of 80 tons per day [4,5]. Its success is made possible by the fact that the sludge removed in the water treatment process is nearly pure calcium carbonate. Operation was begun in January, 1949, and the plant was in full production by April of the same year. The product contains, usually, 92 to 95% of available Calcium Oxide. During 1950, the average cost per ton of lime, including $3.00 per ton for interest and amortization, was $9.99.

Free Residual Prechlorination a Feature

The main purpose of free residual prechlorination is to reduce the organic color of the water. It also, of course, guarantees further the sterility of the water, and reduces total organic matter, tastes and odors.

Prior to the practice of free residual chlorination, water was softened to an average hardness of 85 ppm. Excess lime treatment gave the lowest tastes, odors and color. Slight to moderate tastes and odors were apparent, but final color ranged from 22 to 27. Elaborate and exhaustive experimental work, under the direction of Dr. A. P. Black as consultant, was performed in the Department's laboratory at the Hialeah Plant, beginning in 1941. The laboratory work was followed up by pilot plant operation on double treatment with excess lime, secondary alum coagulation (color floc) followed by aeration and stabilization, the use of ozone, and free residual chlorination. This last method was selected as being the most effective and applicable to the conditions prevailing and the requirements to be met.

As originally planned, excess lime treatment was to be followed by the proper conditioning, settling and

CO_2 and Chlorine Application and Retention Basins
(Aeration Basins, Filters and Pump Station Beyond.)

separation of the floc formed in softening, and the water was then to be recarbonated to a pH of about 7.5. Following this, the chlorine was to be added. All available space was utilized in providing for a maximum retention period. After leaving the contact basins, the water was to be aerated for the reduction of tastes and odors and of any nitrogen—trichloride that might be formed. The "causticizer," shown in the plant plan and flow sheet is an Infilco Accellator. Sodium hydroxide was to be produced in this unit, with a feed of slaked lime and soda ash. The caustic soda so produced was to be fed at the exit of the aeration basins for stabilization, without hardness increase, just prior to filtration. [12]

The change-over to this process was made on June 13, 1949—after several days of plant scale trial runs. The indicated chlorine break-point of the softened water was quite uniform at 9.5 ppm chlorine, and enough more was added to produce a residual of about 1.0 ppm in the finished water. The Carbon Dioxide diffuser motors and the causticizer were started. It was possible to see the lowered color appear beyond the chlorine feed-point within a few minutes and to follow the "color front" as it travelled toward the filters.

While tastes and odors in the freshly treated water were good, complaints and other difficulties soon developed. Carbon dioxide control, while not considered to be too critical at the point of application, would upset control of sodium hydroxide later on, and was very difficult. It was controlled at a later date after much tedious design and adjustment of the by-passed CO_2. About the time that the anticipated difficulties in the manufacture and control of the feed of sodium hydroxide began to develop, adjustment and replacement of some part became necessary. These difficulties were, however, quite minor in comparison with the persistent taste and odor problem. Conditions were not uniform throughout the city, but tastes and odors were reported frequently and chlorinous odors were particularly strong in shower baths. A definite odor of nitrogen trichloride arose from the aeration basins. This, as well as the complaints, was not uniform. Most of the time the odor at the plant, as well as from the various points in the distribution system, was quite faint and not objectionable in amount.

Previous information and opinion was to the effect that no true break-point could be effected at elevated pH, within the time available for retention in the plant, nor by the use of the hypochlorites. It was determined in the laboratory that break-points could be obtained when the chlorine was added to water containing as much as 26 ppm hydroxide alkalinity (+26 treatment) and more, by means of the use of either the hypochlorites or chlorine, and further that the reduction of tastes, odors and color was quite as satisfactory as at any normal lower pH valve. The only differences noted were those already known. The speed of the reaction is slowed down a good deal at extremely high pH, and the effect on tastes, odors and in color reduction is not so good, or as controllable. However, very little nitrogen trichloride is formed at pH above 8. [13] The pH, of the

Chlorinator House
Battery of three 3,000 lb./day W&T Chlorinators, with chlorine evaporator on right. Liquid chlorine is piped from single unit tank cars direct to evaporator.

finished water is calculated to be 8.3 to 8.4.

It was at once concluded that the best possible means of avoiding the tastes and odors associated with nitrogen trichloride was to prevent its formation in the first place. Moreover, if the pH could be maintained in the proper range for a stable water, the need for the manufacture and control in the feed of sodium hydroxide, and maintenance of equipment and cost of chemicals, would be removed. Furthermore, a softer water would unavoidably result, since the turbidity carry-over, which would be increased by the slight super saturation and conversion of hydroxide at the recarbonation basins would no longer be carried for a long time at a low pH.

Instructions were accordingly issued to maintain pH in the range of 9.5 to 10.0 prior to the addition of chlorine and to take the Causticizer out of service. The chlorine reduces pH by about 1.3 units in this range, and water goes on the filters, and leaves them, at a pH of 8.4 to 8.8. No shrinkage or build-up in filter sand level has been noted. The effect of the chlorine feed is measured at the exit of the aeration basins. A total residual of 1.0 to 1.5 ppm is maintained. The Laux-Nickel test is used to verify that this *is* a free residual. The clear well residual is not used for control, but falls in the 0.5 to 1.0 ppm range. This is believed to be due to the latent, persistent chlorine demand of the water. It is not due to loss through the filters.

The odor of nitrogen trichloride disappeared. Complaints decreased almost at once, to the vanishing point. Complaints of tastes and odors due to chlorine, of chlorine-like or chlorinous-weedy tastes, are now rare. Two short periods of complaints have occurred since that time. These were both localized in the same area served by a pumping station where the one storage tank had been maintained at the same level for an extended time prior to the complaints periods. It is believed that this storage period is associated with the cause of taste and odor development, since twice drawing down the tank and refilling it resulted in immediate elimination of the complaints, and also since no other area served produced a single complaint.

It was believed that fairly high free chlorine residuals might be gradually developed, and then maintained and controlled, throughout the distribution system. This condition has never been observed. Except for two or three sampling points fairly close to the plant or on direct transmission lines, the maximum chlorine residual remains at 0.2 ppm, below the range of sensitivity of the Laux-Nickel test.

Laboratory tests were made of the softened water kept in glass-stoppered pyrex bottles, completely filled to avoid air-space. These were chlorinated, and enough samples were made of each dosage for there to be a separate bottle to open for each test. 1 ppm chlorine increments were added, up to 15 ppm, to water taken from the clear well, and also superimposed upon a previous series, from 8 to 20 ppm, added to unchlorinated, softened water. Measured residuals decreased rapidly. After standing overnight, a "secondary break-point" of from 15 to 27 ppm was indicated. pH was not adjusted and was quite low with the higher chlorine doses. Bottles were kept out of direct light. More properly, of course, the free residual chlorine was being consumed by organic matter which had no color, and which had resisted the initial dosage of chlorine. The two-hour break-point is not a measure of a residual or latent chlorine demand. Plotted, it gives the characteristic sharp dip, and "V", followed by the 45° straight line. The "V" proceeds to widen, to the right, until the indicated chlorine demand by resection may be 15, 20 or 25 ppm, depending on the elapsed time since the chlorine was added.

Of further interest is the straight-line effect of chlorine on color. In the range of —0.5 to +1.5 ppm from the indicated 2-hour break-point dosage, there is a straight-line percentage reduction in the color. The degree of lime treatment ahead of chlorination seemed to have no influence on the effects. At 0.5 ppm chlorine, 50% of the color remains, and at +1.5 ppm there is 30%.

In Summary

Free residual chlorination has been applied, since June, 1949, in this plant, to a water after excess lime softening. Recarbonation prior to the addition of the chlorine, is carried only far enough to produce a water which will be stable *after* chlorination. No nitrogen trichloride is formed. A separate stabilization procedure is unnecessary. No tastes and odors are apparent, except in stagnation. The water carries enough slowly oxidizable, uncolored organic matter to prevent the maintenance of free residual chlorine at any appreciable distance from the plant, or in stored water at the plant. Color is reduced to an 8 to 12 range from lime softened water of a color of 18 to 30. Colors as low as 5 are frequently reported. Color reduction is a function of the amount of chlorine applied in excess of the 2-hour break-point dosage. An excess of more than 1.5 ppm. results in no further reduction in color.

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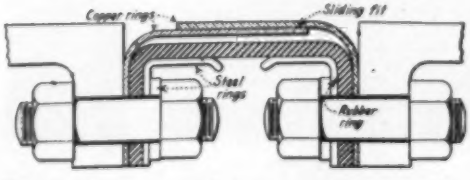
Home-Made Water-Tight Expansion Joint*



Water supply executives will doubtless be interested in this "home-made" expansion joint design by a large Eastern engineering concern. It was designed in order to solve an expansion joint trouble. The joint was made leak-proof by means of a rubber ring, as plainly shown in the accompanying sketch. The joint is strong laterally because of the two telescoping copper rings which makes it possible for the joint to withstand considerable pressure. A joint of this kind is excellent for handling water and other fluids that will not attack the rubber.

*Contributed by W. F. Schaphorst, M.E., Newark, N.J.

Coefficient of Friction and Fire Flow

They Go Hand-In-Hand; Both Demand Respect

by D. R. TAYLOR, *General Manager, Baton Rouge Water Works Co. Baton Rouge, La.*

A MAN who goes to his physician annually for a physical examination is wise. This annual visit enables him to keep a close check on the efficiency of his heart and the friction loss in his arteries. At the first sign of any inefficiency of his "pump" or an increase in the friction head in his circulatory system, he can take immediate remedial action instead of waiting until a major maintenance or construction project is necessary.

What About Water Plant Arteries?

A water plant, like a "human plant," is a valuable investment and at least 50 to 60 per cent of its worth is represented by its transmission and distribution systems. It is also wise to make a routine analysis of the condition of these arteries. An occasional determination will indicate whether or not these mains are losing their capacity, causing an increase in pumping costs or losing their effectiveness for fire protection. Such a study is usually made by determining the coefficient of friction of the mains in question and comparing these coefficients with values which are considered to be standards. This coefficient is represented by the letter "C" in the Williams and Hazen formula. With the aid of a conversion of the original formula and some small equipment, the procedure for obtaining the value of "C" is simple.

The coefficient of new cast iron mains can safely be assumed to be 120 for sizes less than 16 in. and up to 130 for 16 in. and larger, when well laid. For cement lined cast iron mains and concrete mains the value will equal 140. Modern chemical treatment as well as modern lining materials and techniques can preserve these high coefficients for a much longer period than was possible in previous years. The trend of coefficients of mains in any plant will indicate if chemical treatment or a change in chemical treatment is necessary. It will also indicate if cleaning and/or lining is advisable.

Mains are designed for the future; therefore, it has been customary to design with a value of 100 for "C", to allow for some diminution or deterioration of carrying capacity within ten, twenty, thirty or more years.

There are some plants which have raw or finished water of such high quality which is so perfectly chemically balanced, that they, at the risk of stepping on some conservative toes, design with a value of 120 for "C". A record of coefficients of mains of various ages is of considerable benefit to any plant, for the purpose of design as well as to indicate when it is economically urgent to correct deficiencies.

How To Find "C"

In order to determine the "C" for a main, it is necessary first to measure the friction loss in a known length of the main. For this purpose, two accurate pressure or altitude gages are used. These gages should be tested before they are used and if there is any difference in their registration over the range used, this difference should be corrected, or, if this is not possible, a curve should be made for the one which is "off" so that its readings can be reconciled with the accurate one.

Lengths of mains from several hundred feet to several miles may be tested. Relatively long lengths and high flows are more conducive to accuracy, because both cause higher total friction loss and a quarter of a pound or a one foot error in reading either gage will result in a smaller percentage of error in a twenty foot friction loss than in a five foot friction loss.

Rates of flow may be measured with a flow meter if the line being tested is metered, as for instance the discharge from a pumping station or a treatment plant or if it is a distribution main, the measurement may be made through the hose nozzle of one or more fire hydrants. To measure the flow through a fire hydrant, it is necessary to use a hand pitot tube, to which is attached a very accurate pressure gage, a test gage if possible. Furthermore it is necessary to carefully caliper the inside diameter of the fire hydrant nozzle, because these diameters vary with different types of fire hydrants. If one fire hydrant furnishes an insufficient rate of flow or if adjacent property may be damaged if the hydrant is open too much, as many hydrants as necessary may be used to obtain the desired rate.

If the main is fed from both ends, a valve must be closed, so that all of the flow is in one direction. The hour selected for the test should be at a time when there is no consumption from that portion of the main between the gages. Either one or both gages may be attached to fire hydrants by means of drilled and tapped hose nozzle caps or to yard spigots.

If attached to a fire hydrant the hydrant may be fully opened but in any event it should be opened enough to close the drip valve. If attached to

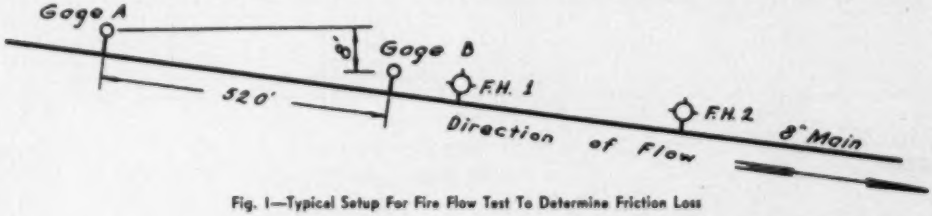


Fig. 1—Typical Setup For Fire Flow Test To Determine Friction Loss

a yard spigot, arrangements must be made with the property owner for no water to be used in the house during the test. It is better if possible to close the stop and waste on the plumbing, if it is beyond the yard spigot, to be sure that there is no usage during this period. If the centers of the two gages are not exactly at the same elevation, the difference in elevation must be carefully measured, in order to make the proper correction when making the computation, otherwise the difference of pressures indicated by the two gages will include the difference of static head as well as friction head and the calculated results will be seriously in error.

Example

Figure 1 shows a typical setup for determining the friction loss in a main. This main consists of 8 in. bell and spigot super de Lavaud cast iron pipe. Gage A is attached to a fire hydrant and gage B is attached to a yard spigot. In order to obtain a sufficient rate of flow without damaging adjacent property, fire hydrants 1 and 2 were used. The difference of elevation of the centers of the gages was found to be 8 feet. The diameter of the hose nozzle of both fire hydrants was found to be 2½ in. and the rate of flow through each fire hydrant was measured simultaneously by a man at each fire hydrant. In this case only one rate of flow was made; however, quite often two or even three rates of flow are used, so that the value of "C" may be calculated for each of them and compared or averaged for the sake of accuracy. In making the calculations the exact inside diameter of the pipe should be used. Diameters for every kind and size of pipe can be obtained from any of the many pipe catalogues and hand books.

Formulas

When:

Q = gallons per minute
C = coefficient of friction

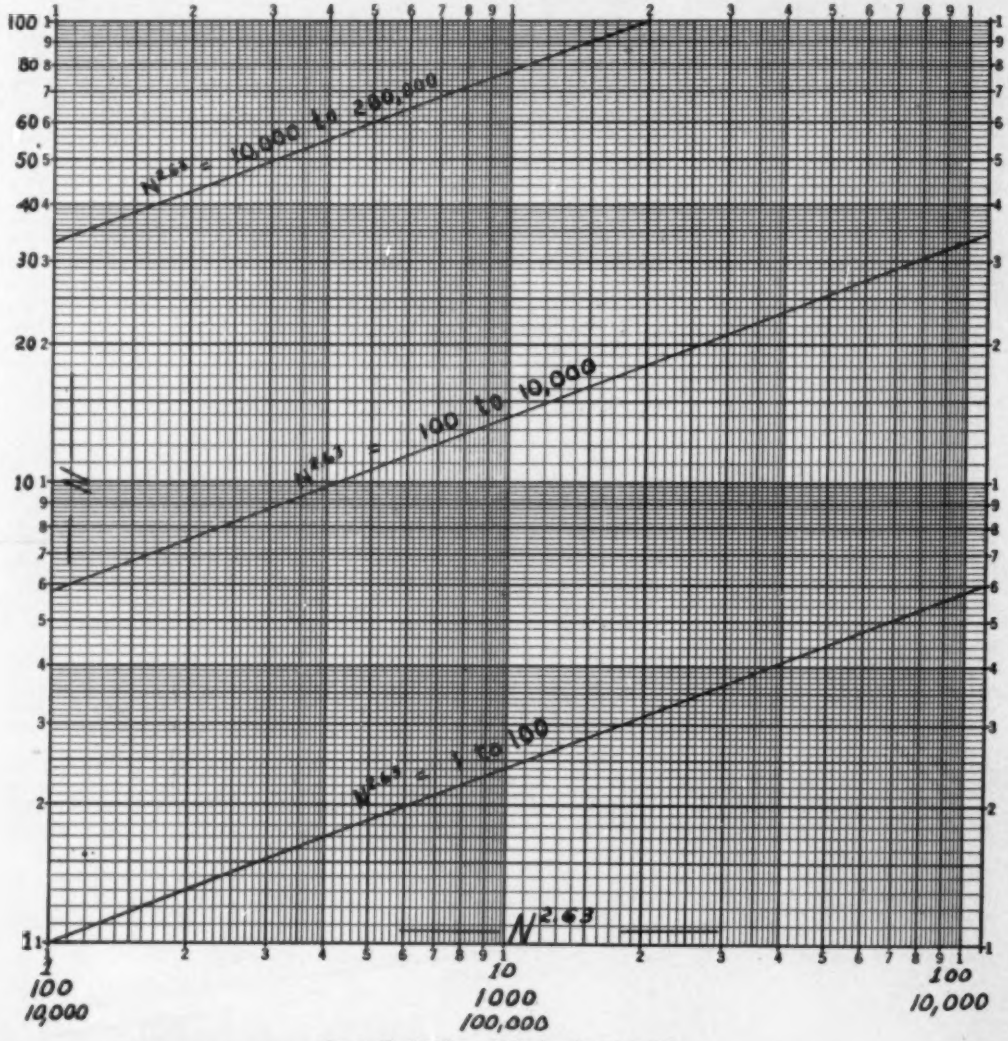


Fig. 2—The 2.63 Power of Numbers from 1 to 100

D = inside diameter of pipe in inches

H = head in feet

H_f = friction head (loss) in feet per 100 feet of pipe

gpm = gallons per minute

psi = pounds per square inch

PD = pressure drop in pounds per square inch

KWH = killowatt hours

M = millions of gallons per day

T = time in days

PE = pump efficiency as a decimal, i.e. .78

ME = motor efficiency as a decimal, i.e. .95

OPE = overall plant efficiency = PE × ME

Q_1, C_1, H_{f1}, PD_1 = values known or considered first

Q_2, C_2, H_{f2}, PD_2 = values unknown or considered second

$$Q = \frac{C\,D^{2.63}\,H_f^{0.54}}{42.7} \quad (1)$$

$$C = \frac{42.7\,Q}{D^{2.63}\,H_f^{0.54}} \quad (2)$$

$$H_f = \left(\frac{42.7\,Q}{C\,D^{2.63}}\right)^{1.85} \quad (3)$$

$$H_{f2} = H_{f1}\left(\frac{C_1}{C_2}\right)^{1.85} \quad (4)$$

$$H_{f2} = H_{f1}\left(\frac{Q_2}{Q_1}\right)^{1.85} \quad (5)$$

$$Q_2 = Q_1\left(\frac{H_{f2}}{H_{f1}}\right)^{0.54} \quad (6)$$

$$Q_2 = Q_1\left(\frac{PD_2}{PD_1}\right)^{0.54} \quad (7)$$

$$Q_2 = Q_1\left(\frac{PD_2^{0.54}}{PD_1^{0.54}}\right) \quad (8)$$

$$Q_2 = Q_1\left(\frac{C_2}{C_1}\right) \quad (9)$$

$$KWH = \frac{3.15 \times H \times M \times T}{OPE} \quad (10)$$

In formula (10) the type of H being considered may be designated by an identifying post-fix. For instance, friction head, discharge head, suction head and total dynamic head may be indicated as H_f, H_d, H_s and H_t. Knowing the number of killowatt hours and the power rate, the total energy cost may be found by multiplying one by the other. This total, however, will not include the load charge, which will be explained later.

The Test Procedure

The following information was obtained before making the flow test:

Inside diameter of pipe (D), 8.21 in.

Distance between gages A and B, 520 ft.

Inside diameter of fire hydrant hose nozzles, 2½ in.

Difference of elevation of centers of gages A and B, 8 ft.

Fire hydrants 1 and 2 were opened about one-half fully open, enough to be sure that the drip valves were closed. Rate of flow was measured from each fire hydrant simultaneously

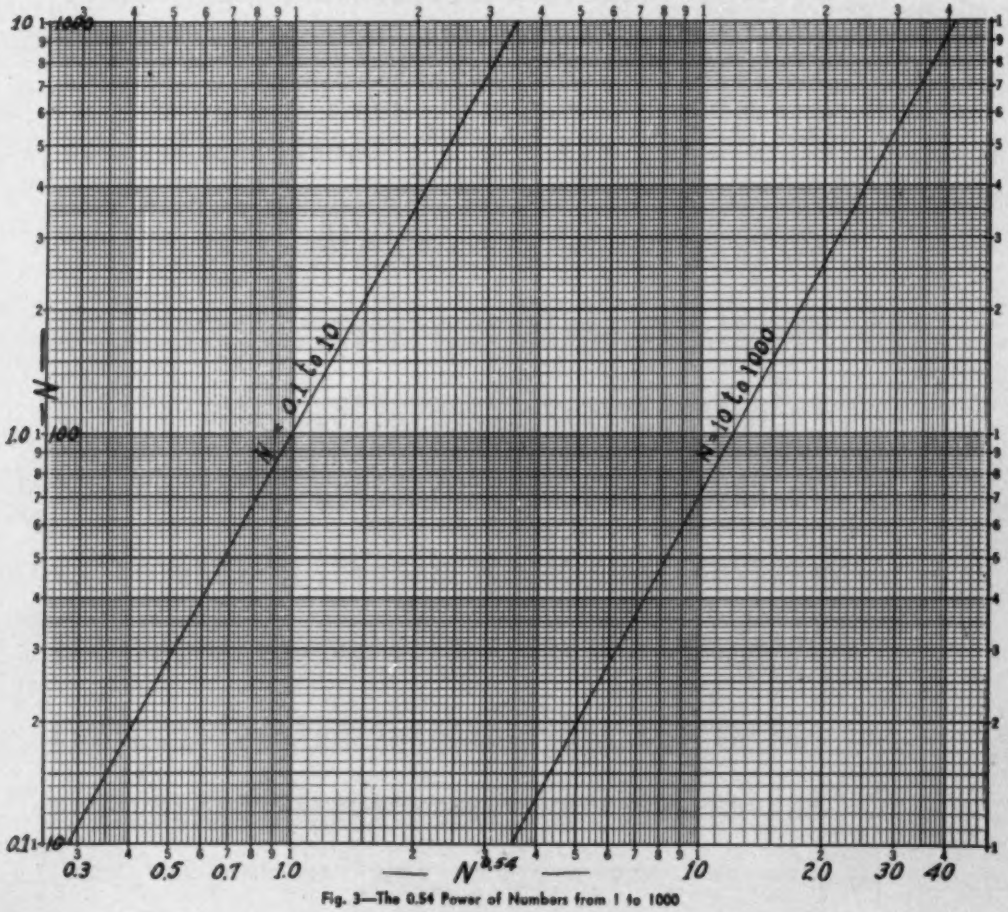


Fig. 3—The 0.54 Power of Numbers from 1 to 1000

Table 1

DISCHARGE TABLE FOR CIRCULAR OUTLETS

Outlet pressure measured by pitot gauge.

Outlet Pres. in lb. per sq. in.	OUTLET DIAMETER IN INCHES							
	2 1/16	2 3/16	2 5/16	2 7/16	2 1/2	2 5/8	2 3/4	2 7/8
	Gallons per Minute							
¼	70	70	80	80	80	90	90	100
½	90	100	110	110	120	120	130	140
¾	120	120	130	140	140	150	160	170
1	140	140	150	160	170	180	180	190
¼	150	160	170	180	190	200	210	220
½	170	180	190	200	210	220	230	240
¾	180	190	200	210	220	230	240	260
2	190	200	210	230	240	250	260	270
¼	200	220	230	240	250	260	280	290
½	220	230	240	250	270	280	290	310
¾	230	240	250	260	280	290	310	320
3	240	250	260	280	290	310	320	340
¼	250	260	270	290	300	320	330	350
½	250	270	280	300	310	330	350	360
¾	260	280	290	310	330	340	360	370
4	270	290	300	320	340	350	370	390
¼	280	300	310	330	350	360	380	400
½	290	300	320	340	360	370	390	410
¾	300	310	330	350	370	380	400	420
5	300	320	340	360	380	390	410	430
¼	310	330	350	370	390	400	420	440
½	320	340	350	370	390	410	430	450
¾	330	340	360	380	400	420	440	460
6	330	350	370	390	410	430	450	470
¼	340	360	380	400	420	440	460	480
½	350	370	390	410	430	450	470	490
¾	350	370	390	410	440	460	480	500
7	360	380	400	420	440	470	490	510
¼	370	390	410	430	450	480	500	520
½	370	390	410	440	460	480	510	530
¾	380	400	420	440	470	490	510	540
8	380	410	430	450	480	500	520	550
¼	390	420	430	460	480	510	530	560
½	400	420	440	460	490	510	540	560
¾	400	420	450	470	500	520	550	570
9	410	430	450	480	500	530	550	580
¼	410	440	460	480	510	540	560	580
½	420	440	470	490	520	540	570	600
¾	420	450	470	500	520	550	580	600
10	430	450	480	500	530	560	580	610

Outlet Pres. in lb. per sq. in.	OUTLET DIAMETER IN INCHES							
	2¼	2 3/16	2 5/16	2 7/16	2½	2 5/8	2¾	2 7/8
	Gallons per Minute							
10¼	440	460	480	510	540	570	590	620
½	440	470	490	520	540	570	600	630
¾	450	470	500	520	550	580	610	630
11	450	480	500	530	560	590	610	640
¼	460	480	510	530	560	590	620	650
½	460	490	510	540	570	600	630	660
¾	470	490	520	550	580	600	630	660
12	470	500	520	550	580	610	640	670
½	480	510	540	560	590	620	650	690
13	490	520	550	570	610	640	670	700
½	500	530	560	590	620	650	680	710
14	510	540	570	600	630	660	690	730
½	520	550	580	610	640	670	700	740
15	530	560	590	620	650	680	720	750
½	540	570	600	630	660	700	730	760
16	540	570	610	640	670	710	740	780
½	550	580	620	650	680	720	750	790
17	560	590	620	660	690	730	760	800
½	570	600	630	670	700	740	770	810
18	580	610	640	680	710	750	780	820
½	590	620	650	690	720	760	790	820
19	590	630	660	700	730	770	810	840
½	600	640	670	700	740	780	820	860
20	610	640	680	710	750	790	830	870
21	620	660	690	730	770	810	850	880
22	640	670	710	750	790	830	870	910
23	650	690	730	760	810	850	890	930
24	670	700	740	780	820	860	910	950
25	680	720	760	800	840	880	920	970
26	690	730	770	810	860	900	940	990
27	710	750	790	830	870	920	960	1010
28	720	760	800	840	890	930	970	1020
29	730	770	820	860	910	950	990	1040
30	750	790	830	870	920	970	1010	1060
31	760	800	840	890	940	980	1030	1080
32	770	810	860	900	950	1000	1040	1100
33	780	830	870	920	970	1010	1060	1110
34	790	840	880	930	980	1030	1070	1130
35	810	850	900	940	990	1040	1090	1140
36	820	860	910	960	1010	1060	1110	1160

with hand pitots, by holding the impact orifice of the pitot in the center of the hose nozzle (center of the stream). The nozzle must be flowing full to get accurate results. At the same time that the pitot readings were taken, gages A and B were read. The test required four men, one at each fire hydrant, one at gage A and one at gage B. The readings of the gages were as follows:

Pitot gage at hydrant 1	17 psi
Pitot gage at hydrant 2	15 psi
Gage A	50 psi
Gage B	32 psi

The Calculation

From Table 1 it will be seen that for a 2½ in. nozzle and a pitot gage reading of 17 psi., that the rate of flow is 690 gpm. and for a pitot gage reading of 15 psi. that the rate of flow is 650 gpm., therefore, Q equals 690 plus 650 or 1340 gpm.

Gage A, 50 psi = 50 × 2.31 = 115.50 ft.
Gage B, 32 psi. = 32 × 2.31 = 73.92 ft.
Diff. of elev. of gages. 8.00 ft

Total Friction Loss =
115.5 − (73.92 − 8.00) = 49.59 ft.

The difference of elevation of gages A and B must always be added to the reading of the highest gage or subtracted from the reading of the lowest gage to correct for this difference. In this case it is subtracted from the reading of the lowest gage.

The total friction loss of 49.58 ft. represents the friction loss in the pipe between gages A and B. The distance between these gages was 520 ft., therefore, the friction loss per 100 ft. of pipe was 49.58 /5.2 or 9.53 ft.

By formula (2),

$$C = \frac{42.7 \times 1340}{8.21^{1.85} \times 9.53^{.54}}$$

From Fig. 2,
$8.21^{1.85} = 255$
From Fig. 3,
$9.53^{0.54} = 3.4$
Therefore,

$$C = \frac{42.7 \times 1340}{255 \times 3.4} = 66$$

What Does This Mean?

It has been found that the friction loss for a "C" of 66 is 9.53 ft. per 100 ft. of pipe. The friction loss for the same rate of flow and "C" of 100 must now be found for comparison. $H_{f1} = 9.53$, $C_1 = 66$, $C_2 = 100$ and H_{f2} is desired.

By formula (4),

$$H_{f2} = 9.53\left(\frac{66}{100}\right)^{1.85}$$
$$= 9.53 \times 0.66^{1.85}$$

From Fig. 4,
$0.66^{1.85} = 0.46$
Therefore,
$H_{f2} = 9.53 \times .46 = 4.38$ ft.

The friction loss for a "C" of 100 would be 4.38 ft. per 100 ft.

Friction loss for a "C" of 66 = 9.53 ft.
Friction loss for a "C" of 100 = 4.38 ft.
Excess friction loss per 100 ft. = 5.15 ft.

Expressed another way, the friction loss for a "C" of 66 is 9.53 / 4.38 = 2.17 times that for a "C" of 100.

Why Worry About It?

Let it be assumed that the same conditions exist in the discharge pipe of a well pump, discharging into a header serving a treatment plant or discharging directly into a distribution system, through 300 ft. of 8 in. pipe with a "C" of 66 and at the same rate of 1340 gpm. The overall plant efficiency is .726 and the total dynamic head is 204 ft. which includes the friction loss of 9.53 ft. per 100 ft. or a total friction loss of 3 × 9.53 or 28.59 ft.

$$M = \frac{1340 \times 1440}{1{,}000{,}000} = 1.9296 \text{ say } 1.93$$

Total KWH for 30 days is as follows:

By formula (10),

$$KWH = \frac{3.15 \times 204 \times 1.93 \times 30}{.726}$$
$$= 51{,}248$$

With a "C" of 100 the friction loss in this discharge would be 3 × 4.38 ft. or 13.14 ft., which is 15.45 ft. less than that for a "C" of 66 and the total dynamic head would be 204 — 15.45 or 188.55 ft. Total KWH for 30 days with this head would be as follows:

By formula (10),

$$KWH = \frac{3.15 \times 188.55 \times 1.93 \times 30}{.726}$$
$$= 47{,}367$$

KWH per month with "C" of 66 = 51,248
KWH per month with "C" of 100 = 47,367
Difference 3,881

Let's Consider The Power Cost

In the power contract the load charge is fixed by the size of the motor, however, the total energy charge varies with the KWH used. The rate schedule for energy is as follows:

First	1500 KWH	2.0¢ per KWH
Next	3500 KWH	1.5¢ per KWH
Next	45000 KWH	1.0¢ per KWH
Additional	KWH	.8¢ per KWH

Due to the fact that the first 50,000 KWH are included in the first three steps in the rate schedule and 51,248 KWH were consumed, it is readily evident that 1248 KWH were in the fourth step and the remaining 2633 KWH were in the third step. The excess monthly power cost, therefore, was as follows:

2633 KWH @ 1.0¢ = $26.33
1248 KWH @ .8¢ = 9.98
$36.31
Excess cost per year = 12 × $36.31 = $435.72

This figure represents the actual excess power cost or waste of power in pumping against the excess friction loss, resulting from the low coefficient of friction.

This discharge pipe should of course be replaced with a larger pipe with allowance made for the same rate of reduction of "C" that occurred before or it could be replaced with cement lined pipe, designed with a "C" of 140. Formula (3) is useful for the design of pipe lines. By selecting a maximum allowable friction loss and a "C" of 140 for cement lined pipe or a "C" for unlined pipe that would be expected at the end of the period for which the line is designed, one or more diameters (D) can be tried in formula (3) and a quick solution obtained.

This discharge was too small when it was first installed and represents poor design. If designed with a "C" of 100, the friction loss would be 13.14 ft. or 5.7 psi. and this is too much for only 300 feet of pump discharge.

The saving in power cost would pay the cost of the new pipe within a few years. For instance it will be found with formulas (3) and (10) that a 10 in. cement lined cast iron discharge would have a friction loss of only about 0.995 ft. per 100 ft. and would save $749.76 per year in power cost. After deducting the slight increase in fixed charges resulting from the increase in plant value, the new line could be paid for from savings in about two years, which amounts to a 50 per cent return on the investment, which is certainly an astronomical figure in the water works field, and shouldn't be ignored.

Conditions such as those illustrated actually exist and this somewhat extreme example is cited to emphasize the importance of the subject.

Another Illustration

Another illustration is that of an 8 in. main 2000 ft. long and fed only from one end. It was designed with a "C" of 100 to furnish a required fire flow of 1000 gpm. to a fire hydrant at the end of the main, with a residual pressure of 20 psi. The static pressure at the point of connection to the distribution system was 50 psi. which allowed a pressure drop of 30 psi. or 69.3 ft. or 3.465 ft. per 100 ft. Actual inside diameter of the

pipe was 8.21 in. The design was as follows:

By formula (1),

$$Q = \frac{100 \times 8.21^{2.63} \times 3.465^{0.54}}{42.7}$$

From Fig. 2,

$8.21^{2.63} = 255$

From Fig. 3,

$3.465^{0.54} = 1.96$

$$Q = \frac{100 \times 255 \times 1.96}{42.7}$$

$$= 1170 \text{ gpm.}$$

A test of the main when completed revealed a gratifying rate of flow of 1450 gpm. with the desired residual pressure, indicating a "C" of 123.9. Twelve years later it was found that the fire hydrant produced only 900 gpm. with a residual of 20 psi. By formula (2) the "C" for this rate of flow was found to be 76.9, but most important was the fact that the rate of flow was below that required to satisfy the fire protection requirements.

The importance of maintaining a high value of "C" for gravity mains, in which case the total head is fixed, is emphasized when by formula (9) it is found that a main installed with a "C" of 120 has lost 42 per cent of its carrying capacity when its "C" has decreased to 70.

Fire Flow Test

Fire flow tests are easy to make. In the majority of cases, fire flow requirements are designated as a specific rate of flow with a residual pressure of 20 psi. in the main. In a few cases a residual pressure of 10 psi. is accepted, when other requirements are exceeded.

Fire flow capacity is determined by ascertaining the pressure drop for one or more rates of flow and then with these data, calculating the rate of flow for a pressure drop equal to the difference between the static pressure and 20 psi. For the same reasons previously explained, better accuracy is obtained with relatively large pressure drops than with small ones. Also two or more rates of flow will provide a more accurate test than one.

The Setup

Rates of flow may be measured by flow meter or fire hydrants just as for the test for "C." It is necessary to attach only one gage to the main. Theoretically, the residual pressure is assumed to be at the elevation of the main; however, the elevation of the gage, for all practical purposes, may be anywhere from the center of the main to the hose nozzle of the fire hydrant normally used. If the gage cannot be located between these limits, the proper correction should be made in the calculation. Usually in testing 6 in. and 8 in. mains, it is necessary to "flow" only one fire hydrant. For larger mains or distribution system tests, two, three or even four hydrants may be necessary to obtain the desired rate of flow. If only one hydrant is used, the pressure gage may be attached to another hydrant a block away or it may be attached to a yard spigot near the hydrant. In either case, all of the precautions mentioned in the description of the test for "C" should be taken.

If two hydrants are used, the gage may be attached to a hydrant at a street intersection and any other two hydrants a block away in any two directions may be selected for the flow test. For instance, one may be one block north of the gage and the other one block east, south or west of the gage, or the gage may be attached to a yard spigot between the two hydrants to be "flowed." If three or four

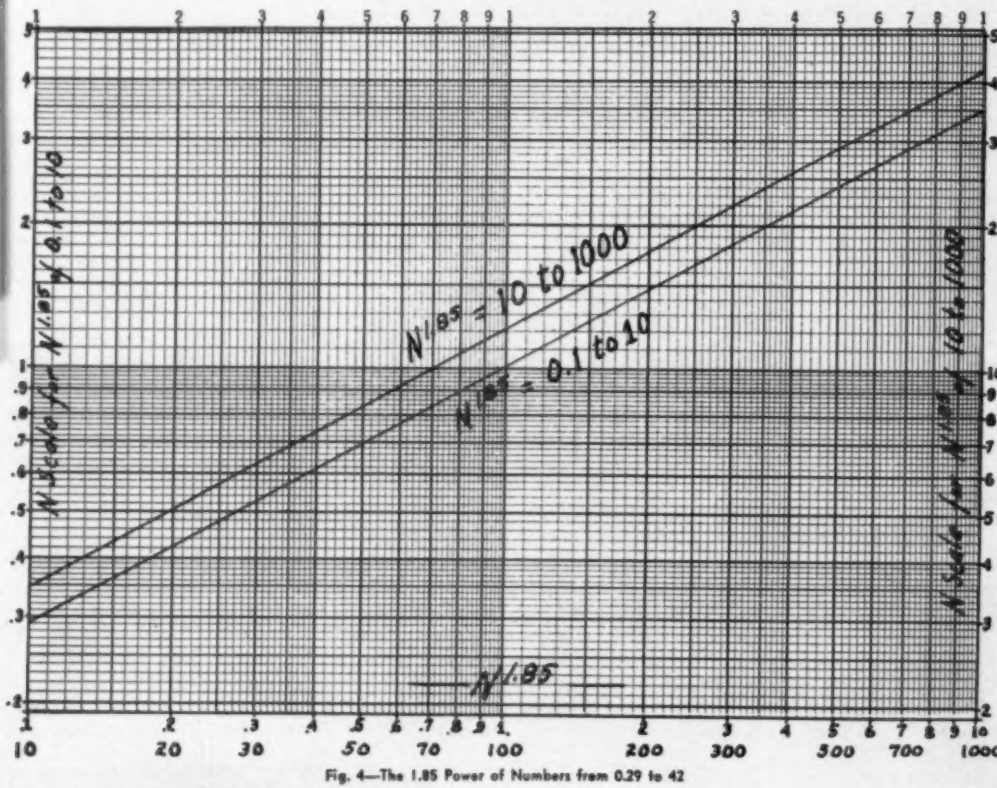


Fig. 4—The 1.85 Power of Numbers from 0.29 to 42

hydrants are used for the test, the gage should be located in a relatively central position with respect to the hydrants being used, so that the pressure drop will be representative of all of them as well as the system being tested.

A Typical Test

Assume that a fire flow test is to be made in a residential section on an 8 in. main in a distribution system. A pressure gage has been attached to a fire hydrant. A hydrant one block away is to be used to obtain the rate of flow and the inside diameter of the hose nozzle has been found to be 2½ in. The first hydrant has been opened completely to be sure that the drip valve is closed and the static pressure reading has been noted and recorded.

The second hydrant is then opened several full turns of the operating nut and a pitot reading made and recorded. At the same time the pressure gage on the other hydrant is read by an assistant. The hydrant is then opened several more turns and similar readings again noted and recorded. The same procedure is repeated for a third set of readings.

The Results

Static pressure in main 60 psi.

First pitot reading 6½ psi.
From Table 1, Q = 430 gpm
Residual pressure in main 56 psi.
Pressure drop (PD) = 60 — 56 = 4 psi.

Second Pitot reading 14 psi.
From Table 1, Q = 630 gpm
Residual pressure in main 52 psi.
Pressure drop (PD) = 60 — 52 = 8 psi.

Third pitot reading 18 psi.
From Table 1, Q = 710 gpm
Residual pressure in main 50 psi.
Pressure drop (PD) = 60 — 50 = 10 psi.

The rate of flow that can be obtained with a residual of 20 psi. must now be calculated. With such a residual pressure the pressure drop will be 60 — 20 = psi. When the values of pressure drops are fractional numbers such as 8½, formula (7) and Fig. 3 may be used, but when these values are whole numbers as in this case formula (8) and Table 2 may be more convenient as illustrated in the following calculations:

1. $Q_1 = 430 \times \frac{40^{0.54}}{4^{0.54}} = 430 \times \frac{7.33}{2.11} = 1492$ gpm.

2. $Q_2 = 630 \times \frac{40^{0.54}}{8^{0.54}} = 630 \times \frac{7.33}{3.07} = 1505$ gpm.

3. $Q_3 = 710 \times \frac{40^{0.54}}{10^{0.54}} = 710 \times \frac{7.33}{3.47} = \frac{1498}{4495}$ gpm.

Average $Q = \frac{4495}{3} = 1498$ gpm.

The rate of flow that may be expected from this hydrant with a residual of 20 psi. is therefore 1498 gpm.

Make Both Tests at Same Time

The fire flow test can be made at the same time that the test for "C" is made. For instance when the previously described test for "C" was made, the static pressure reading of gage B could have been noted before hydrants 1 and 2 were opened and then noted again when the two hydrants were flowing. With the pressure drop thus obtained and the rate of flow obtained during the test, the capacity of the main for fire protection with a residual of 20 psi. could have been found with the use of formula (7) or (8).

Other Uses Of Formulas

A few trial calculations with formula (4) will illustrate how rapidly friction loss increases when "C" decreases. With formula (5) the increase of friction loss as compared with an increase in the rate of flow is indicated and formula (6) shows the relationship between rate of flow and friction loss. Formula (9) reveals the relation of rate of flow and coefficient of friction.

Table 2

TABLE OF VALUES OF (H) NUMBERS RAISED TO THE 0.54 POWER

H	$H^{0.54}$	H	$H^{0.54}$	H	$H^{0.54}$	H	$H^{0.54}$	H	$H^{0.54}$	H	$H^{0.54}$	H	$H^{0.54}$
1	1.00	26	5.81	51	8.36	76	10.37	101	12.09	126	13.62	151	15.02
2	1.45	27	5.93	52	8.44	77	10.44	102	12.15	127	13.68	152	15.07
3	1.81	28	6.05	53	8.53	78	10.51	103	12.22	128	13.74	153	15.13
4	2.11	29	6.16	54	8.62	79	10.59	104	12.28	129	13.80	154	15.18
5	2.39	30	6.28	55	8.71	80	10.66	105	12.34	130	13.85	155	15.23
6	2.63	31	6.39	56	8.79	81	10.73	106	12.41	131	13.91	156	15.29
7	2.86	32	6.50	57	8.88	82	10.80	107	12.47	132	13.97	157	15.34
8	3.07	33	6.61	58	8.96	83	10.87	108	12.53	133	14.02	158	15.39
9	3.28	34	6.71	59	9.04	84	10.94	109	12.60	134	14.08	159	15.44
10	3.47	35	6.82	60	9.12	85	11.01	110	12.66	135	14.14	160	15.50
11	3.65	36	6.93	61	9.21	86	11.08	111	12.72	136	14.19	161	15.55
12	3.83	37	7.03	62	9.29	87	11.15	112	12.78	137	14.25	162	15.60
13	4.00	38	7.13	63	9.37	88	11.22	113	12.84	138	14.31	163	15.65
14	4.16	39	7.23	64	9.45	89	11.29	114	12.90	139	14.36	164	15.70
15	4.32	40	7.33	65	9.53	90	11.36	115	12.96	140	14.42	165	15.76
16	4.47	41	7.43	66	9.61	91	11.43	116	13.03	141	14.47	166	15.81
17	4.62	42	7.53	67	9.69	92	11.49	117	13.09	142	14.53	167	15.86
18	4.76	43	7.62	68	9.76	93	11.56	118	13.15	143	14.58	168	15.91
19	4.90	44	7.72	69	9.84	94	11.63	119	13.21	144	14.64	169	15.96
20	5.04	45	7.81	70	9.92	95	11.69	120	13.27	145	14.69	170	16.01
21	5.18	46	7.91	71	9.99	96	11.76	121	13.33	146	14.75	171	16.06
22	5.31	47	8.00	72	10.07	97	11.83	122	13.39	147	14.80	172	16.11
23	5.44	48	8.09	73	10.14	98	11.89	123	13.44	148	14.86	173	16.16
24	5.56	49	8.18	74	10.22	99	11.96	124	13.50	149	14.91	174	16.21
25	5.69	50	8.27	75	10.29	100	12.02	125	13.56	150	14.97	175	16.26

How Remedy Ills?

No specific recommendations can be made to cure the ills illustrated, because the remedy depends upon the history of the plant and all local conditions and aims. Each plant must be considered individually.

If the solution consists only of replacing a few hundred feet of pipe or something equally simple, no outside assistance may be needed, but if the problem seems to be a major one, the services of a reputable engineering firm should be engaged immediately. Such an investment will usually pay large dividends.

The magnitude of the trouble often is dependent upon the size of the plant and the ability of its engineering staff. A minor ailment may be cured with household remedies, but the treatment of coronary thrombosis or hardening of the arteries requires a specialist.

Herman Burgi, Jr.
Gen'l Manager
P. W. D.

Everett O. Boothby
Superintendent
P. W. D.

Helen C. Frost
President
Portland City Council

Chas. Ray. Moore
Asst. Chief Engr.
P. W. D.

Harold B. Scales
Chief Chemist
P. W. D.

Portland Water District Hosts, and M.W.U.A.'s No. 1 Guest

Maine Water Association Holds 25th Portland Meeting

FOR the 25th year the Maine Water Utilities Assn. held its Annual Midwinter Meeting in Portland, Me.

As for many years past, the Portland Water District acted as host, the featured manufacturers' exhibits and technical sessions being staged in the commodious Service Building of the District, which is likewise distinctive for its architectural attractiveness and utilitarian facilities.

As also, for many years, those in attendance were guests of the District at an opening supper on February 13th, served by employees of the District. Those who have read in this magazine earlier reports of these Portland meetings may recall the glowing appraisal of P.W.D.'s clam chowder and doughnuts, both fully up to Maine standards. Well, this year, if anything the chowder was even better and the doughnuts bigger than ever before. This writer sought out the employee responsible for the chowder. He was photographed and we present to you "P.W.D.'s Master Chowder Maker" on page 2 of this report. With regrets for the oversight, we have no celluloid record of the recipiency by this "doughnut fiend" of a much appreciated package of Portland doughnuts from the P.W.D. Management as "a special order of business" at the evening session.

At the mid-day dinner on the second day of the meeting the registered attendance announced by Secretary Earle Tarr was 194, representing a composite of more than 3,000 years of waterworks service.

M.W.U.A. Brass

Secretary
Earl A. Tarr, Supt., Winthrop, Me.

President & Editor
Sidney S. Anthony, Supt., Augusta, Me.

Program Chairman
J. Elliott Hale, Supt., Waterville, Me.

As stated previously, a distinctive feature of the Portland meetings are the exhibits of equipment and materials and ample opportunity for demonstrations, shop-talk and questions during the opening afternoon and forenoon of the second day. The two technical sessions amount to a day of presentation of papers and committee reports, to comprise a well rounded out meeting.

First Technical Session

Following the chowder supper, Herman Burgi, Jr., Manager and Treasurer of the Portland Water District, acting as M.C., introduced members of the P.W.D. Board of Trustees. A brief welcome was extended by P.W.D.'s Board President, S. T. Bennett.

Then followed an interesting highlighting, by Manager Burgi, of the history of Portland's water supply and in more detail recent and current development under the P.W.D. regime.

Mr. Burgi outlined the history of Portland's water supply from 1866 to 1908 when the system was purchased from the Portland Water Co. by the newly formed Water District of Portland, which has gradually enlarged its operations since 1908. As of today Portland and nine other communities are served under the P.W.D. charter, which is the equivalent of that of a municipality of extended area encompassing many communities and rural areas. The District is managed and operated as a profit making corporation, maintaining a sinking fund equal to a yearly surplus of between 1% and 5% of the entire indebtedness of the Utility. It is mandatory that rates be maintained to provide all expenses and the specified surplus for the retirement fund.

Equipment and Materials Exhibits and Shop Talk
In the Service Bldg. and Shop of the Portland Water Distr.

Speaker
Genl. J. L. Ready
Asst. Director
Maine Civil Defense

Speaker
David B. Hoyer
Phg. Agri. Chem. Co.
New York

The system, with its great asset in Lake Sebago as the source of supply, was then described in brief and followed by a somewhat detailed account of expansions in 1949 and 1950, involving extensions of many miles of mains, replacement of small mains and two complete new systems, representing an expenditure of $1,000,000 in 1950 and a projected expenditure of another million for a new lake intake and other planned improvements.

In financing the two new systems and major main extensions annual payment by water takers, and the towns served, in the amount of 8% return on the investment had been established by contract.

Mr. Burgi pointed to the fallacy of laying 8 in. pipe for a main of any appreciable length when for a comparatively little extra cost 10 in. pipe can be used to great advantage. At the extra cost of less than 75 cents per foot of pipe a capacity gain of 75% is procurable with the 2 in. larger 10 in. pipe. He also pointed out the marked gains through the purchase of mechanical equipment for the new construction and day to day maintenance and repairs. Amongst the equipment added were a ½ yd. Wayne Back-Hoe with 31 in. bucket; a Hough "Payloader"; three air-compressors and tools; a Gar Wood 2,750 lb. Hoist (17 ft. radius) Mack Tractor mounted, with trailer for hauling pipe; several dump trucks, etc.

Mr. Burgi called attention to P.W.D.'s good fortune in getting a 500,000 gal. elevated tank and a 350,000 steel standpipe erected ahead of present restrictions on steel plate. He also pointed out the interesting observation that salt water in Portland Harbor gets down to 26°F. at the bottom. Therefore water mains must be laid in a deep trench on the harbor bottom to preclude freezing of the mains supplying South Portland across the harbor.

The balance of the evening was devoted to showing of films of the atomic bomb explosions and results in the South Pacific demonstrations and studies of effects and after-effects. Also the atomic blast film "Pattern for Survival" was shown as part of the Civil Defense program.

Luncheon Session

On the second day the high-light of the Luncheon Session was the appearance of the No. 1 Guest—the lady chairman of the City Council of Portland, Mrs. Helen C. Frost. Mrs. Frost, after pleasing remarks of welcome, surprised many, perhaps, with her knowledge of water supply and developments in fluoridation. She closed with the expressed hope that P.W.D. management give thoughtful consideration to fluoridation of Portland's water, and also her desire to have the management sit with the Council and discuss the feasibility of introducing fluoridation in Portland for the benefit of the younger generation. Mrs. Frost's position in the City Manager government of Portland is the equivalent of that of mayor.

Distinguished Visitors

Thos. L. Camp
Cons. Engr.
Boston
(Pres. N.E.W.W.A.)

W. H. Daniels
Supt.
Hudson, N. H.
(Pres. N.H.W.W.A.)

Civil Defense in the State of Maine

Brigadier Gen. J. L. Ready (Retired), Asst. Director Maine Civil Defense, outlined progress in the defense program in Maine. The Maine plan is that of units for each county with a chief and five deputies. The No. 1 deputy has the responsibility for water supply. It developed that there have been very few water supply men appointed, however.

Free Dinner
Leon V. Cyr
Trustee
Van Buren, Me.
(Travelled farthest to meeting)

Major-Domo
Percy H. Belyea
Foreman
Port. Water Distr.
("Master Chewder Maker")

Brush and Aquatic Weed Killers

David B. Hoyer, Pittsburgh Agricultural Chemical Co., New York City, described the methods of brush growths and weed killing with such materials as 2-4-D for broad leafed plants and the newer 2-4-5-T for woody growths. The principle of destruction is that of over-stimulation of growth activity and the equivalent of hyper-tension and death from exertion.

For water-hyacinth and alligator weed 2-4-D was recommended at the rate of 2 lbs. of acid equivalent per acre for the hyacinths and 8 lbs. for alligator weed. The acid equivalent value of the material per gallon is stated on the container by law. Therefore, in purchasing, one must compare costs on the basis of pounds of acid equivalent per dollar. The 2-4-D is an amine and is non-toxic to fish or animals. It is also effective on cat-tails and duck weed. For cat-tails about three years of repeated application will be required to secure complete eradication of all surviving root growth.

In spray application it is preferable to use a relatively low pressure (150 lbs. or under) to secure the more effective droplets rather than a mist.

For briars, thorn bushes, poison ivy and the like 2-4-5-T is the most effective killer. Kerosene or Diesel oil is the preferable solvent for the compound and coarse spray is superior. The combination, known as Pitts-

Equipment and Materials Exhibits and Shop Talk
In the Service Bldg. and Shop of the Portland Water District.

Oldtimers
"Jim" Caird
Cons. Chemist, Troy, N. Y.
(53 yrs. in Water Supply)
and
Joe Lathrop, Pres.
Red Head Mfg. Co., Boston
(65 yrs. in W. W. Business)

Farthest Travellers
Leon Cyr
Water Distr. Trustee
Van Buren, Me.
and
Louis Dumais
Supt.
Van Buren, Me.

Dependables
M. C. Carson
Utility Man.
P. W. D.
and
C. P. Rennell
Foreman
P. W. D.

Ambassadors of Commerce
Walter Arnold
Genl. Manager
and
Roger Esty
Service and Sales Engr.
Water Wks. Supply Co.
Lynn, Mass.

Senator and "Super"
Senator Geo. D. Boulter
*Water Board Chairman**
and
Francis L. Hatch, Supt.
Kittery, Me.
*(*37 yrs. on the Board;*
29 yrs. as Chairman.)

burgh 10-20 Brush Killer is offered for both brush and plant growth. It is a combination of 2-4-D and 2-4-5-T and three applications per growing season will eradicate 50 to 75 % of the unwanted growths. It will not harm the soil or sterilize it. The cost for three applications will average about $15.00 per acre as against $75.00 if done manually. After the first year the cost diminishes.

In the operation 100 gals. of spray is prepared by adding 1½ to 3 gals. of the 10-20 combination to 100 gals. of water. Apply 100 gals. per acre, a coarse spray being best employed. The larger and tougher growths can more effectively and economically be killed by cutting and applying the spray to the stump.

Water Fluoridation

Reporting as Chairman of the Committee on Water Quality Standards, Harold B. Scales, Chief Chemist, Portland Water District, reviewed the history of Water Fluoridation and developments of recent times. The report was factual and without recommendations at this juncture. Mr. Scales commended that the published policy of A.W.W.A. in regards to fluoridation and approval of the treatment by such states as Wisconsin, Michigan, New York, Florida and Virginia, was having far-reaching effect in advancing fluoridation.

Asked for some remarks on this subject, L. H. Enslow, Editor of *Water & Sewage Works*, presented a brief review of the first five years of fluoridation and the recent rapid expansion of this scheme of fortification of fluoride poor waters. It was his understanding that no harmful effects had been observed in the communities chosen for the close observation of effects during the first five years. The results had been sufficiently impressive to justify the expense involved, and waterworks managers should not make the mistake of trying to argue the matter if the proper local interests desired the treatment for the potential 50% effectiveness in reducing tooth decay of the youngsters. Introduction of fluoridation offered a ready opportunity to secure rate increases where needed.

Expert and "Wheel-horses"
James M. Caird, Troy, N. Y.
P.W.D.'s Consulting Chemist

Maurice A. Libby, Bath, Me.
Bath Water Distrs., "Supr."

Edwin T. McDowell, Augusta, Me.
Maine Utilities Comms. Chief Engr.

In reply to questions, Mr. Enslow was of the opinion that little hazard existed in the matter of dosage control, since the range of 1 ppm. to 1.5 ppm. deemed satisfactory represented a dosage variation of 50% up or 33% down, as one chooses to consider it. If at small plants hypochlorination could be satisfactorily controlled on fully automatic pumping systems, then fluoridation should pose no new or more difficult problem. Check up tests at the local high school could be made by the chemistry teacher in lieu of a Health Dept. laboratory. Certainly a request to the State or County Health Dept. would bring assistance in getting underway with fluoridation, and arranging for routine control and testing.

In summary, said Mr. Enslow, as a water works manager he would think many times before saying no to someone like the Chairman of Portland's City Council if she asked if we shouldn't try fluoridation for the benefit of our children.

Legislative Committee Report

Chairman Burgi called attention to the Maine requirements that Water Utilities must apply for permits to locate mains, valve boxes and fire hydrants along highways, just as other utility companies are required to do. He pointed out an instance in which one water utility was forced to pay damages to the owner of the car that wrecked a fire hydrant and the car. The Public Service Commission had not approved the hydrant location and the hydrant was held to be improperly located and without the required permit.

In the matter of Water Pollution Control, Maine is now considering the matter of joining with the other New England States in the existing compact, as against the establishment of a new State Pollution Control Board.

The meeting closed with a rising vote of appreciation to the P.W.D.

New Officers in A.W.W.A. Declared Elected

In our February issue we reported the official nominees for offices in the Am. Water Works Ass'n which we said was tantamount to election on March 1st, automatically. These were:

President—Albert E. Berry
Vice-Pres.—Chas. H. Capen
Treasurer—Wm. W. Brush

Now that the period permitted by the Constitution for additional nominations by the membership at large expired as of March 1st, 1951, the above nominees have been automatically elected and will take offce at the close of the Annual Meeting of A.W.W.A. in Miami, Fla., April 29-May 4, to serve during the period between the 1951 and the close of the 1952 Annual meeting on July 1, 1952.

A.W.W.A. Convention Program

Miami, Fla., April 29-May 4

Miami Bound

HEREWITH the interim program covering the technical sessions of the Miami Convention of A.W.W.A. In releasing the program, Secretary Jordan points out that minor changes may be necessary, but essentially the final program will not differ from the following:

TECHNICAL SESSIONS

MONDAY, APRIL 30—10:00 A.M.

Committee on Water Works Practice.....*(L. R. Howson)*
Committee on Water Works Administration.....*(W. R. LaDue)*
(Open Sessions)

MONDAY, APRIL 30—2:00 P.M.

Meter Maintenance Costs.....*A. P. Kuranz*
Meter Reading and Billing Costs.....*Kenneth K. King*
Automotive Equipment Costs.....*James A. Ramsey*
Water Rates Committee Report.....*Louis E. Ayres*

MONDAY, APRIL 30—2:00 P.M.

Soluble Copper Salts for Water Treatment.....*M. C. Smith*
A New Device for Odor Determination.....*H. H. Gerstein*
Committee Reports—
Purification Plant Wastes.....*W. W. Aultman*
A. P. Black, Martin E. Flentje
Open Air Reservoirs.....*Norman J. Howard*
Fluoridation Practices.....*Jerome Zufelt et al*

TUESDAY, MAY 1—9:30 A.M.

Water Pipe Joint Rings Compounded with Synthetic and Natural Rubber.....*W. L. White*
Should All Water Pipe Design Include Allowance for Water Hammer?.....*S. Logan Kerr*
Some Illustrations of the Value of Analyzing Pipe Networks.....*Malcolm S. McIlroy*
Recent Research in the Performance of Sulfur Jointing Compounds.....*Raymond B. Seymour*

TUESDAY, MAY 1—9:30 A.M.

Removal of Radio-active Substances from Water.....*Rolf Eliassen*
Discussion.....*H. Gladys Swope, Arthur E. Gorman*
Instrumentation of the Water Examination Laboratory.....*S. K. Love*
Discussion.....*Edw. S. Hopkins*
Further Research in Diatomite Filtration.....*Jos. C. Sanchis*
John C. Merrell
Discussion.....*John E. Kiker*

TUESDAY, MAY 1—2:00 P.M.

Report of Committee on Compensation of Water Works Personnel.....*Leon A. Smith*
Survey of State Highway Department Practices re Cost of Relocation of Water Works Facilities.....*Harry B. Shaw*
Task Group Report—Safety Programs for Water Works.....*Raymond J. Faust*

TUESDAY, MAY 1—2:00 P.M.

Studies in Local Production of Chlorine.....*Chas. A. Black*
Carl M. Hoskinson
Lime Reclamation at the Miami Softening Plant.....*C. F. Wertz*
Discussion.....*H. V. Pedersen*
Conditioning Sodium Silicate with Chlorine.....*A. E. Griffin*

WEDNESDAY, MAY 2—9:30 A.M.

The Report of the Presidents Water Policy Commission.....*Samuel B. Morris*
The Water Works Industry's Interest in National Water Policy.....*Abel Wolman*
Objectives of a National Water Policy.....*Malcolm Pirnie*
Local and Regional Water Supply Management.....*H. E. Jordan*
Discussion.....*Dale Maffitt*
Fred Merryfield, A. G. Mathews

WEDNESDAY, MAY 2—2:00 P.M.

Safe Yield of Ground Water Sources (Panel Discussion)
Introduction.....*Malcolm Pirnie*
Geologic and Hydrologic Factors.....*V. T. Stringfield*
Miami Water Supply.....*G. C. Parker*
Construction and Operation of Wells.....*Paul Schweitzer*
Discussion.....*A. P. Black*
R. M. Leggette, W. A. Glass

Committee Report:
Recommended Practice for Sealing Abandoned Wells.....*J. C. Harding*
Mortality of Water Wells.....*H. E. Hudson*
J. L. Geils
Discussion.....*A. E. Fawcett*
W. A. McEllhinney, H. E. Lauman

THURSDAY, MAY 3—9:30 A.M.

Industry's Water Requirements.....*Roy R. Green*
Discussion.....*W. F. Guyton*
D. J. Saunders, E. B. Showell
Applications of the Heat Pump.....*N. C. Ebaugh*
Discussion.....*C. R. Erickson*
Family Income and Residential Water Consumption.....*H. E. Hudson*
B. O. Larson
Fluctuations in Water Use and Revenue.....*W. E. Banks*
Walter Boquist, Richard Bonyun
H. M. Ohland

THURSDAY, MAY 3—2:00 P.M.

Water Requirements of Various Types of Users.....*L. J. Hoffman*
Seasonal Water Demand in Vacation Areas.....*S. K. Keller*
Discussion.....*Maurice Brunstein, H. T. Critchlow*
Henry Barksdale, A. H. Fletcher
Water Rates for Low Load Factor Water Users.
Panel Discussion by *M. P. Hatcher, F. C. Amsbary,*
L. E. Ayres, L. L. Lewis, W. V. Weir

THURSDAY, MAY 3—2:00 P.M.

Water Supply Developments in Latin America:
Introduction.....*A. P. Black*
Puerto Rico.....*Sergio Cuevas*
Cuba.....*Manuel Puente*
Mexico.....*M. A. Mantilla*
H. R. Alvarez, Armando Gutierrez
Venezuela.....*J. R. Hurtado*
Colombia.....*L. L. Guerrero*

FRIDAY, MAY 4—9:30 A.M.

Water Works and the Defense Program—

Critical Materials, Priorities, Allocations	Leader—*Wendell R. LaDue*
Civilian Defense	Leader—*John S. Longwell*
Radio Communications	Leader—*M. B. Cunningham*

Fig. 1.—Interior of Tank: Left, Uncleaned Corroded Paint—Right, Sand Blasted and Painted

Repainting Steel Water Tanks*

by J. O. JACKSON,** *Vice Pres. in Charge of Engineering & Research, Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.*

CORROSION prevention is unquestionably the most important item in steel water tank maintenance. While other methods of corrosion control such as cathodic protection and metallic coatings are effective in many instances, paint remains the most important method of preventing or reducing corrosion in steel water tanks. This article outlines the best known methods of surface preparation and suggests several paint systems which have been found to be most dependable and effective in general use.

The painting of steel water tanks involves several types of surfaces: the interior water immersed surfaces, the surfaces above the maximum water level, and the surfaces alternately wet and dry, the exterior or weather exposed surfaces, and the underside of flat tank bottoms which are inaccessible after the tank is completed. The underside of steel tank bottoms on concrete or clean gravel undergoes very little corrosion and seldom requires more than occasional reflashing around the outside circumference.

Outside Surfaces

The outside surfaces of steel water tanks are exposed to the weather, the nature of which varies from a corrosive industrial atmosphere, a non-corrosive rural atmosphere, desert heat and dry climates, tropical humidity and rainfall, and salt air or sea coast locations.

Paint is almost always used to protect outside surfaces although there have been cases of sprayed metal protection and hot applied coating used in acute corrosive conditions such as in chemical plants and sea coast locations.

Inside Surfaces

The interiors of steel water tanks have been protected from corrosion in a number of ways. These include cathodic protection, metallic coatings, wax or grease coatings, hot coatings and linings, cement linings, and paints. The life of all interior protection is affected to some degree by the chemical nature of the stored water. This varies considerably in different localities. Instances are known where a certain paint which gives good wood protection in one locality is entirely removed from the inside surface of a tank within a few weeks in another locality. Owners of steel water tanks must therefore determine the best method of protecting the inside surfaces of their tanks to suit the chemical nature of their water.

If no suitable materials of reasonable cost are known to be satisfactory for a given water, it is suggested that a test be made by dividing the interior of a tank into sections and painting with several types of paints and placed in service. Periodic inspections will soon divulge the best paint for any condition. For further information on conducting tests, including suggested paints, see article entitled "Experimental Studies of Tank Coating Materials," *Jour. of Amer. Water Works Assn.*, Sept. 1941.

CATHODIC PROTECTION has been found to be quite effective in moderate climates but is not recommended for cold climates where ice may damage the electrodes. Where cathodic protection is used, the intermittently wetted surfaces and the surfaces above the high water level should be painted.

SPRAYED METALLIC COATINGS are very effective with corrosive waters. They are usually covered with a plastic paint or coating to reduce the inherent porosity of the sprayed metal. Zinc is most effective because of its sacrificial protection of the tank steel and because of its proximity to iron in the electromotive series. The cost of sprayed metal coatings properly protected is much more than for most paints.

WAX OR GREASE COATINGS are often very effective in interior tank protection. If the water is clean and there is no violent agitation of the tank contents, this material should be considered. Instances are known where the interiors of tanks have been adequately protected for more than fifteen years with a single application of a heavy grease coating. There have also been instances of unsatisfactory service with materials of this type.

HOT COATINGS include materials which are applied hot and which harden on cooling to a more or less plastic condition. Among these are coal tar, natural asphalt, and synthetic plastics and linings. Many of these are excellent coatings for water tank insides. Some are quite expensive both as to the cost of materials and application. They deserve consideration in cases where less costly paints are unsuitable.

CEMENT LININGS may be either portland or other cements or mixtures. They have been successfully used in many localities where other materials have given trouble.

PAINTS are the most generally used protective material for water tank insides. If the surface is properly prepared and a

*A "Guide for Tank Maintenance Inspection," by Mr. Jackson, appears in the Reference and Data Section of this issue.

**Member A.W.W.A., Committee on Elevated Steel Water Tanks, Standpipes and Reservoirs. Chairman, Research and Publications Committee, Steel Structures Painting Council.

suitable paint formulation is used, satisfactory and economical protection can be obtained in most localities. Because paint is the generally preferred method and because in some cases unsuitable paints and faulty surface preparation methods have been used, there is included hereafter a detailed discussion of surface preparation and a number of recommended paint systems which have been found to give excellent protection with most types of water.

The secret of successful and economical paint protection is:

1. Proper Surface Preparation.
2. Suitable Paint Materials.
3. Proper Application to Required Thickness.
4. Proper Maintenance of the Paint Film by Annual Inspection and Repair.

Surface Preparation

Paint applied over dirt, rust, loose mill scale or blisters cannot give satisfactory protection. If the old paint is in good condition it will be so hard and tight that it will be difficult to remove, and if it is clean and not too thick it will be satisfactory to leave in place. Cleaning may be done by hand or power wire brushing, hand scrapers, sand or emery paper, or by blasting.

The best method to use will depend upon the surface to be cleaned and the amount to be done. For field cleaning including the removal of old paint, sand blasting is the best and usually the least expensive method for equally good results. To do effective sand blasting a nozzle with a ¼ in. diameter orifice should be used. This will require an air supply of at least 100 cubic feet of free air per minute with a pressure just ahead of the nozzle of at least 90 psi. A lower pressure will not do economical or effective blasting.

With the suggested equipment from two to three square feet of surface can be cleaned per minute (actual blasting time) with a sand consumption of about 50 pounds per 100 square feet of surface cleaned, based on screening and using the sand twice. The sand should be purchased especially for blast cleaning and should be of a hard sharp silica type from 20 to 40 mesh grain size. The surface should be cleaned until it is a uniform gray color without discolored spots or areas. The insides of all pits should be blasted until clean.

Sand blasting is usually the best method of removing an old coat of paint because it does it economically and at the same time cleans the steel surface. In cases where blast cleaning cannot be used because the dust and grit are objectionable, the old paint may be removed by burning with a blow torch or with the oxyacetylene torch or with paint strippers. Paint strippers are chemical cleaners usually used with a high pressure steam generator and will remove large areas of paint economically. Before painting the stripped surface should be treated with a chemical rust remover and inhibitor such as specified in U. S. Dept. of Commerce, Letter Circular 744, dated 2-26-44, "Painting Steel Potable Water Tanks."

Figure 1 illustrates a tank being blast cleaned. This tank is at Ambridge, Pa., and is used as a test of various kinds of blast cleaning and types of paint.

Figure 2 shows the same tank as Fig. 1 and illustrates a steel dolly which provides a very convenient platform for both blasting and painting.

Paint Application

After an area of convenient size, usually one day's work, has been cleaned as above, all bare places where steel is exposed should be brushed with one coat of rust inhibitive primer before any rusting or surface discoloration takes place. After the primer coat has dried hard such surfaces should be brushed or sprayed with one or two coats as specified. Surfaces which have not been previously painted or from which all the old paint has been removed should be protected with at least a three coat system. Where the old paint is in good condition, two additional coats are usually satisfactory.

No painting should be done with oil type paints when the temperature is below 35°F, or upon wet, frosty, or dirty surfaces. The paint should be mixed and thinned as recommended by the manufacturer. If sprayed on, suitable nozzles should be used for spraying, with pressure on the liquid and atomizing nozzle within the ranges recommended by the paint and equipment manufacturers. Sprayed paint should preferably be applied in two layers at right angles to each other to obtain more uniform thickness.

If brushed on, the paint should be applied in one direction and smoothed in a direction at right angles to produce a coating of more uniform thickness. Each coat should be applied to the specified minimum dry film thickness. The interior paint finish should be allowed to dry until hard before filling the tank with water. With an oil type paint this usually requires several days in a well ventilated tank. With quicker drying paints the time will be shorter.

The question of whether brushing or spraying should be used is a subject of considerable discussion. It has been proved that on a clean surface spraying will produce a better paint coat than brushing because it will be more uniform in thickness, will not have depressions caused by brush bristles and will fill pits more uniformly. However, on a dusty or dirty surface the sprayed coat may lie on top of the dust and fail to adhere. Therefore, brushing is better for dirty surfaces because the brushing works the dirt into the paint and does not reduce adhesion. Spraying while fast and effective must be properly done. The correct air pressure, nozzle orifice and technique should be used. Where available workmen are not skilled in spraying paint it is safer to brush. If nearby property might be damaged by spray mist, brushing is advisable.

Fig. 2.—Open Top Tank Being Blast Cleaned—Blast Machine is in Center—Blast Cleaned Area at Left—Dolly on Casters Provides Scaffold at Convenient Levels and Is Easily Moved

PAINT SYSTEMS FOR INTERIOR SURFACES

Paint System No.		1.1*	1.2*	1.3*	1.4*
Must mill scale be removed		No	Yes	No	Yes
Number of Coats		2 or 3	2 or 3	2 or 3	4
1st Coat	Pigment	Red Lead-Iron Oxide	Red Lead	Red Lead-Lead Chromate**	Basic Zinc Chromate
	Vehicle	Linseed Oil-Alkyd	Phenolic	Phenolic	Vinyl
2nd and 3rd Coat	Pigment	Red Lead	Red Lead	Blue Lead-Zinc Oxide***	Red Lead
	Vehicle	Phenolic	Phenolic	Phenolic	Vinyl
4th Coat	Pigment	x	x	x	Aluminum
	Vehicle	x	x	x	Vinyl-Alkyd

PAINT SYSTEMS FOR EXTERIOR SURFACES

Paint System No.		2.1*	2.2*	2.3*	2.4*
Must mill scale be removed		No	Yes	No	Yes
Number of Coats		2 or 3	2 or 3	2 or 3	4
1st Coat	Pigment	Red Lead-Iron Oxide	Red Lead	Red Lead-Lead Chromate	Basic Zinc Chromate
	Vehicle	Linseed Oil-Alkyd	Phenolic	Phenolic	Vinyl
2nd and 3rd Coat	Pigment	Aluminum, Black, Gray or Green	Aluminum, Black, Gray or Green	Aluminum, Black, Gray or Green	Red Lead
	Vehicle	Alkyd	Alkyd	Alkyd	Vinyl
4th Coat	Pigment	x	x	x	Aluminum, Black, Gray or Green
	Vehicle	x	x	x	Vinyl-Alkyd

*** See Appendix for detailed specifications for the paint systems outlined above.**
**** Used also for 2nd coat in the three coat system.**
***** Used as 2nd coat in two coat system but as 3rd coat in the three coat system.**

Health Hazards

To prevent disaster and damage to personal health the following precautions should be observed in repainting tanks.

SAND BLASTING. To avoid silicosis hazards men should wear masks with fresh air supply when working inside of closed or poorly ventilated tanks and should wear air filters at all other times.

CLEANING WITH SOLVENTS must not be done in unventilated spaces. All paint solvents produce toxic or suffocating vapors which usually are inflammable. Test atmospheres for inflammable conditions before and during cleaning with solvents.

PAINTING. Most paint vapors are hazardous to health and are inflammable, especially in closed spaces. Painters should wear fresh air masks. Ventilate sufficiently to avoid explosive atmospheres.

Paint Systems

Unless all of the old paint has been removed exposing clean metal it is advisable to repaint the tank with a primer which will be compatible with the old paint. The solvent action of many synthetic vehicles may lift and blister the paint underneath or adjacent to the area being painted. Some of the more recently developed paint systems give excellent protection, but only if applied over steel surfaces from which all mill scale and old paint have been removed by blasting. Recommended paint systems for steel water tanks are shown in the accompanying charts—"Paint Systems for Interior and Exterior Surfaces."

Paint Maintenance

A tank should be inspected at least once a year. The tank should be drained and the interior allowed to dry so that the paint can be properly inspected. Defects in the paint coat such as blisters, rust, or abraded spots should be repaired so that they will not progress to extended failure of the paint film.

If the mill scale has been previously removed the defects which appear in the paint film will usually be very small in area and will mostly be the result of abrasion or minor blistering. These small areas should be cleaned and repainted with the same materials with which they were painted originally.

Thorough annual inspection and spot painting in this manner will materially increase the life of the paint system, and complete repainting should not be necessary for several years. There will be very little deterioration of the steel and the tank should last indefinitely.

If the mill scale has not previously been removed, the surfaces should be examined carefully to determine whether the defects are due to incidental abrasive damage or to mill scale lifting. Mill scale usually fails from moisture getting under it and lifting the scale and the paint on top of it away from the steel surface. This exposes a rusted area under the mill scale resembling improperly cleaned steel.

If there are only a few defects, these should be cleaned and repainted as above, but if there are mill scale failures occurring over the entire tank it would be unwise to clean and repaint these spots because this type of failure is progressive and more spots will continue to appear. It is then a never ending job to properly repair the paint film. In such a case it is advisable to completely remove the old paint film and the remaining mill scale by sand blasting, and to repaint such sandblasted surfaces.

The American Water Works Assn. has published a "Recommended Practice for Inspecting, Repairing and Repainting Elevated Steel Water Storage Tanks, Standpipes and Reservoirs," Publication No. 7H, 2-5, latest revision. Copies may be obtained by addressing the Association at 500 Fifth Avenue, New York 18, N. Y. These recommendations were published in the AWWA Journal for October, 1948.

Appendix

1. DETAILS OF PAINT SYSTEMS RECOMMENDED FOR INTERIOR SURFACES.

1.1 For use over clean steel or clean tightly adhering mill scale and tightly adhering old paint:

1.11 First Coat:

Paint: Red Lead-Iron Oxide primer in a linseed oil-alkyd vehicle.

Specification: Federal Spec. TT-P-86a-Type II.

How Applied: Brush or Spray.

Film Thickness: 1.5 mils minimum.

Description: This paint dries for handling or recoating in about 16 hours. The vehicle consists of raw linseed oil blended with a glyceryl-phthalate type varnish composed of a linseed oil modified alkyd resin with the necessary driers and volatile thinners. The free linseed oil in this paint has more wetting power than the type IV, for better bonding with the metal surface and for sealing the mill scale.

1.12 Second Coat:

Paint: Red Lead primer in a phenolic vehicle.

Specification: Federal Spec. TT-P-86a-Type IV.

How Applied: Brush or Spray.

Film Thickness: 1.5 mils minimum.

Description: This paint has excellent water impermeability and exhibits good resistance to acid and alkaline environments. It dries for handling or recoating in about 6 hours. The vehicle for this paint is a straight phenolic spar varnish suitable for grinding with red lead and consists of a varnish composed of 25 gallons of tung oil and 100 pounds of a 100% pure non-harden-

ing phenolic resin plus the necessary driers and volatile thinners.

1. 13 Third Coat:

Paint: Same as second coat item 1. 12.

Note: Three coat paint systems are recommended if the old paint has been entirely removed. Where the old paint is in good condition, a two coat repaint system is satisfactory but the total paint film thickness after repainting should not exceed about 10 mils.

1. 2 For use where mill scale and old paint have been removed by blasting:

1. 21 First Coat:

Paint: Red Lead primer in a phenolic vehicle.

Specification: Federal Spec. TT-P-86a-Type IV.

How Applied: Brush or Spray.

Film Thickness: 1.5 mils minimum.

Description: Same as for paint in item 1. 12.

1. 22 Second Coat:}
1. 23 Third Coat: }

Same as first coat item 1. 21 except that successive coats of paint should be tinted to slightly different colors to help indicate proper coverage.

1. 3 For use whether or not mill scale and old paint have been removed:

1. 31 First Coat:

Paint: Lead Chromate-Red Lead primer in a spar varnish vehicle.

Specification: Pgh-Des Moines Spec. S16482-37.

How Applied: Brush or Spray.

Film Thickness: 1.5 mils minimum.

Description: This paint was rated 100% in both the Ambridge and the Mahoning Valley paint tests. It is designed to have a dull orange surface which provides better adhesion for succeeding coats of paint. It dries for handling or recoating in 24 hours.

1. 32 Second Coat:

Same as first coat 1. 31 but tinted to help indicate proper coverage.

Note: In a two-coat system omit this coat.

1. 33 Third Coat:

Paint: Lead Chromate-Sublimed Blue Lead-Zinc Oxide-Graphite in a water resisting spar varnish vehicle.

Specification: Pgh-Des Moines Spec. F16502-38.

How Applied: Brush or Spray.

Film Thickness: 1.5 mils minimum.

Description: This synthetic gray enamel was rated 100% in the Ambridge tests and 75% in the Mahoning Valley tests.

1. 4* For use where mill scale and old paint have been removed by blasting: (See note following 2. 44)

1. 41 First Coat:

Paint: Zinc Chromate primer in a vinyl vehicle, with an acid diluent.

Specification: Bureau of Ships Paint Formula 117.

How Applied: Spray.

Film Thickness: 0.3 to 0.5 mils.

Description: This metal conditioning wash primer is designed to dry for handling or recoating in 15 to 30 minutes. One part of a phosphoric acid-alcohol diluent is mixed with four parts of the insoluble basic zinc chromate-polyvinyl butyral resin base just before using. It must be used within 8 hours.

1. 42 Second Coat:

Paint: Red Lead primer in a vinyl vehicle.

Specification: Bureau of Ships Paint Formula 119.

How Applied: Spray.

Film Thickness: 1.0 to 1.5 mils.

Description: This anti-corrosive primer dries for handling or recoating in 30 minutes.

1. 43 Third Coat:

Same as second coat item 1. 42 but tinted brown to help indicate proper coverage.

1. 44 Fourth Coat:

Paint: Aluminum powder in a vinyl resin vehicle.

Specification: "Vinylite" Formula XE-5221A.

How Applied: Brush or Spray.

Film Thickness: 1.0 mils minimum.

Description: This paint is available ready to mix or in double compartment containers.

2. Details of Paint Systems Recommended for Exterior Surfaces.

2. 1 For use over clean tightly adhering mill scale and tightly adhering old paint:

2. 11 First Coat:

Paint: Red Lead-Iron Oxide primer in linseed oil-alkyd vehicle.

Specification: Federal Spec. TT-P-86a-Type II.

How Applied: Brush or Spray.

Film Thickness: 1.5 mils minimum.

Description: Same as paint in item 1. 11.

2. 12 Second Coat:

Paint: Aluminum, Black, Gray or Green in an alkyd vehicle.

Specification: Aluminum per PDM Spec. F16430-39, Black per PDM Spec. F16431-39, Gray or Green per PDM Spec. F16433-49.

How Applied: Brush or Spray.

Film Thickness: 1.5 mils minimum.

Description: The aluminum paint consists of 2 pounds of Aluminum paste per Federal Spec. TT-A-466 Type A in one gallon of glyceryl phthalate alkyd resin vehicle per PDM Spec. 16434-39. The black paint consists of carbon black in the same alkyd vehicle. The gray and green tinted paints consist of titanium dioxide together with reinforcing and tinting pigments in the same alkyd vehicle.

2. 13 Third Coat:

Same as second coat item 2. 12 but tinted to help indicate proper coverage.

2. 2 For use where mill scale and old paint have been removed by blasting:

2. 21 First Coat:

Paint: Red Lead primer in a phenolic vehicle.

Specification: Federal Spec. TT-P-86a-Type IV.

How Applied: Brush or Spray.

Film Thickness: 1.5 mils minimum.

Description: Same as paint in item 1.12.

2. 22 Second Coat:}
2. 23 Third Coat: }

Aluminum, Black, Gray or Green in an alkyd vehicle, same as paint in item 2. 12.

2. 3 For use whether or not mill scale and old paint have been removed:

2. 31 First Coat:

Paint: Lead Chromate-Red Lead primer in a spar varnish vehicle.

Specification: Pgh-Des Moines Spec. S16482-37.

How Applied: Brush or Spray.

Film Thickness: 1.5 mils minimum.

Description: Same as paint in item 1. 31.

2. 32 Second Coat:}
2. 33 Third Coat: }

Aluminum, Black, Gray or Green, in an alkyd vehicle, same as paint in item 2. 12.

2. 4* for use where mill scale and old paint have been removed by blasting: (See note following 2.44.)

2. 41 First Coat:

Paint: Zinc Chromate primer in a vinyl vehicle, with an acid diluent.

Specification: "Vinylite" Formula WP-1.

How Applied: Spray.

Film Thickness: 0.3 to 0.5 mils.

Description: Same as paint in item 1. 41.

2. 42 Second Coat:

Paint: Red Lead primer in a vinyl vehicle.

Specification: "Vinylite" Formula XE-5295.

How Applied: Spray.

Film Thickness: 1.0 to 1.5 mils.

Description: Same as paint in item 1. 42.

2. 43 Third Coat:

Same as second coat item 2. 42 but tinted brown to help indicate proper coverage.

2. 44 Fourth Coat:

Paint: Aluminum, Black, or Gray in a vinyl-alkyd vehicle.

Specification: Aluminum per "Vinylite" Formula XE-5221A, Black per "Vinylite" Formula XE-5296, Gray per "Vinylite" Formula XE-5297.

How Applied: Brush or Spray.

Film Thickness: 1.0 mils minimum.

Description: The aluminum paint is available ready to mix or in double compartment containers. The gray paint complies with Bureau of Ships Paint Formula 122. All of these topcoats are quick drying like the vinyl red lead primer. They are much more readily sprayed than brushed although special thinners may be used to improve brushability.

Paint Sources

The specifications referred to in the details of paint systems above may be secured from the following sources:

U. S. Government Specifications—the Superintendent of Documents, Government Printing Office, Washington, D. C.

Pittsburgh Des Moines Specifications——Pittsburgh Des Moines Steel Company, Pittsburgh 25, Pa.

Bakelite Division of Union Carbide and Carbon Corporation, 30 East 42 Street, New York, New York.

To secure the above paints it is only necessary to purchase them from a reliable paint manufacturer who will agree to furnish paints strictly in accordance with the specifications referred to. Where company specifications are given, the company will usually advise the names of current suppliers of paints known to be satisfactory.

*Vinyl Paint Systems No. 1.4 and 2.4 were developed during World War II for painting ship bottoms. They were adopted by the U. S. Navy and Coast Guard who have prepared specifications for their use. These paints are more difficult to apply than oil type paints and require spraying technique similar to lacquers. When properly applied on blasted surfaces they will last much longer than oil type paints. The Vinyl System for ship bottoms is credited with extending the repainting time for ocean going ships from less than one year to over two years.

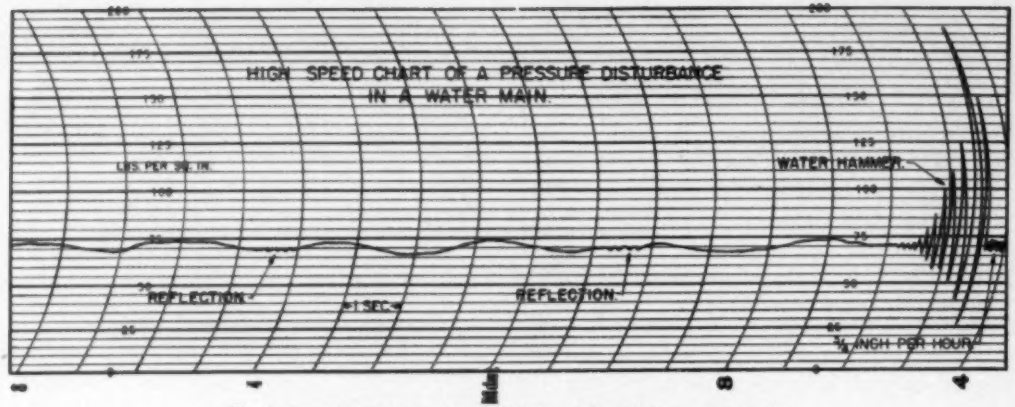


Fig. 1—Record of Esterline-Angus High Speed Graphic Pressure Recorder
(Chart shows destructive pressures and reflection of disturbance.)

Water Hammer Correctives

Part II

by RICHARD BENNETT, *Hydraulic Engineer, City Engineer's Office, Phoenix, Arizona*

SINCE the first publication in *Water & Sewage Works* of an article on "Water Hammer Correctives," there has been a material advance in both knowledge of, and equipment available for, avoiding or eliminating water hammer troubles in water systems. To meet this advance this new article has been prepared as Part II, at the express request of the Editors.

With the exception of some of the data on air chamber sizes, the text and all illustrations are new. By no means is the original article obsolete—the subject is so broad that repetition is unnecessary, therefore, much of that article retains value.

What Is Water Hammer

Hydraulic shock, or "water hammer" continues to be a major water works problem in both supply and distribution. For some situations the solution is both obvious and simple, but in many instances it is complicated and recommendations should be based on competent technical analysis. To meet these situations operators and manufacturers have devised and manufactured surge tanks, air (and mechanical-pneumatic) and diaphragm domes of various designs, stand pipes, relief and by-pass valves, special check valves, they have rebuilt existing piping systems, specifically designed others and have tested many other individual ideas, as well.

Water hammer (which is another name for water surge) is the result of sudden deceleration or stopping of a moving column of water. The Kinetic energy contained in the moving water is dissipated by means of the resulting surge. This surge will equal approximately 54 pounds head for every foot per second of velocity that the water is traveling when suddenly stopped. This surge will oscillate throughout the length of the water column at a velocity of approximately 2500 to 4000 feet per second (varying with diameter, thickness and type of pipe material) until all energy has been used up by friction losses.

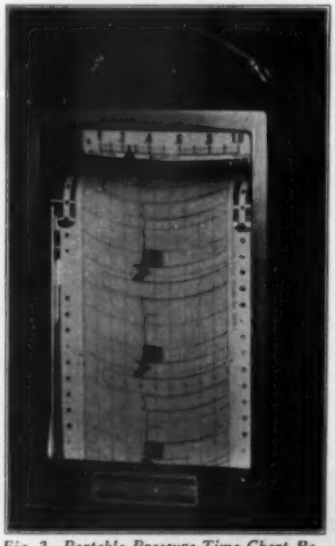


Fig. 2—Portable Pressure-Time Chart Recorder—Esterline-Angus

Variations in piping combinations and conditions tend to set up water hammer. It occurs in all sizes of pipe and variations of pressure. At high rates of speed it may travel and cause great damage to both piping and equipment far removed from the source.

Simple laboratory experiments easily confirm that water hammer is not necessarily accompanied by noise. This phenomenon is confusing to many.

Water hammer elimination equipment must be set close to the point of origin of the trouble or its effectiveness is diminished. Each of the various items of equipment discussed and illustrated possess features of individual value to meet varying local conditions.

Many water works have experienced trouble with cracked water mains, broken check valves, and other operating troubles for which abnormal internal pressures were suspected. How to find the source and extent of these destructive pressures oftentimes becomes a real engineering problem. To determine the source of such surges, and more particularly to determine the results obtained from any corrective measures used, or equipment installed, graphic pressure recorders equipped with high speed chart drives are used.

These instruments accurately record the maximum forces exerted when check valves are suddenly closed. By means of such time-pressure charts, operators are able to analyze and deduce equipment operating characteristics. Once these data are known, proper design specifications can be prepared.

Esterline-Angus Recorder

Figure 1 shows the recorded chart of an actual water hammer occurrence. In this case, repeated bursting of water mains necessitated that this water works study

*Part I on "Water Hammer Correctives" appeared in *Water & Sewage Works*, April 1946, p. R-106.

Fig. 3—Pressure Time Indicator—Bachrach Industrial Instr. Co.
(Suitable for water hammer studies.)

pressures and locate the points where water-hammer was set up. For this investigation they used an Esterline-Angus graphic pressure recorder as shown in Fig. 2, especially equipped with a Cutler-Hammer No. 10014H18 gauge type pressure reverse operation switch.

Equipped with this reverse operation switch, normal operating pressures were recorded with a chart speed of ¾ inch per hour, but when high water hammer pressures occurred the relay closed, increasing the chart speed to ¾ inches per second. The purpose of speeding up the chart is to extend the record so that all water hammer characteristics may be clearly and readily analyzed.

At 4:20 P.M. with the chart operating at normal speed, a pressure disturbance occurred, the relay closed, and the chart shown in Fig. 1 was the result. Analyzing this chart it was found that the pressure rose instantly to 150 psi. then fell to 25, then rose to 185, then down to 40, and up and down as the disturbance subsided. The original disturbance was about one second duration, with a frequency of oscillation of approximately 10 cycles per second.

Analyzing this chart further it is noticed that reflections of the disturbance occurred regularly at intervals of 5.6 seconds. These reflections are like an echo; the waves of pressure traveled until they struck some irregularity in the main and were then reflected back.

Fig. 4—Complete Pressure-Time Recording Set.—Bachrach Indust. Instr. Co.

Knowing the size and type of material in the water main involved, utilizing previous experience, and with subsequent verification tests, it was determined that the pressure wave velocity in the main was 4,700 fps. This particular disturbance had a frequency of 10 cycles per second, therefore, the actual wave length was 470 feet. To create this wave length would require a closed column whose length was one-fourth of a wave length. (For verification of this last statement consult the more technical treatises.) Now it is revealed that the disturbance originated in a section of the main 117.5 feet long.

The reflection of this disturbance occurred every 5.6 seconds, making a total path from the point of measurement to the reflection point and back again, of 26,300 feet. This shows that the reflection point was one-half this distance, or 13,150 feet from the graphic recorder. With these data the exact point of disturbance occurrence was located. Corrective measures and equipment were installed and adjusted in accordance with interpretive data derived from subsequent charts made with the same graphic recorder until all destructive water hammer had been eliminated from that distribution system.

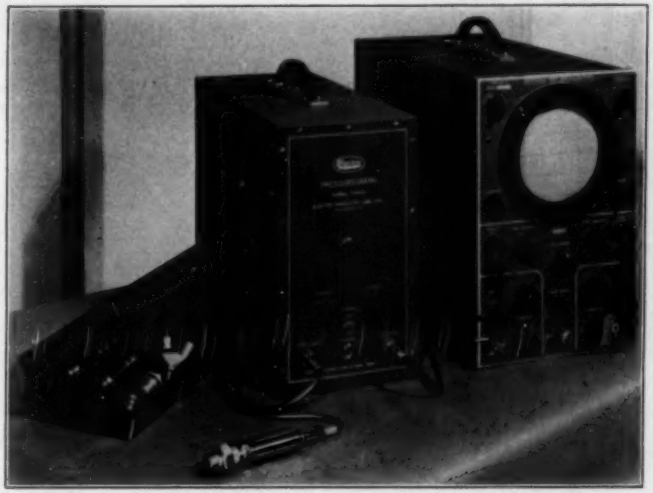


Fig. 5.—Pressuregraph and Cathode Ray Oscillograph—Electro Products Laboratories, Inc.

Bacharach Chronomatic Indicator

One of the best known arrangements for recording water hammer is an engine indicator, such as the Bacharach cantilever spring type, as manufactured by the Bacharach Industrial Instrument Co. This instrument shown in Fig. 3 is designed in such manner that the diagram is traced on paper and is large enough for detailed study. The speed of drum rotation is controlled by the magnetic speed indicator on top of drum. This instrument complete with accessories and boxed for portability is shown in Fig. 4.

Pressuregraph

For reciprocating surges, such as those developed by positive displacement pumps, electronic equipment works very well and give indications of any second or third order vibrations or reflected surges. But for low speed displacement pumps, going about 200 rpm., the Bacharach engine indicator gives excellent results which can readily be understood.

Where high frequency surges are encountered the electro-time-pressure types are necessary. For inside of plant water hammer investigations, very high pressures and very fast hydraulic pressure transients may be encountered. In one machine shop valves designed for 200 psi. working pressure were continually breaking.

To investigate this problem, a Pressuregraph and Cathode Ray Oscillograph indicator as shown in Fig. 5, and manufactured by Electro Products Laboratories, Inc., were used to record the unusual water hammer effects. Other types of equipment used on this case were found to have too much inertia to follow the fast transient curves. Until this equipment was used they had no data to show what was causing this continual valve failure. Pressures in excess of 1,600 psi. were discovered and the oscillograph curves, when analyzed, showed certain operating characteristics which essentially aided in the redesign of the hydraulic system.

In some cases a study of wave outline characteristics of the time-pressure graph, will give a clue to the possible source of trouble as illustrated in Figs. 14, 15 and 16, which show three characteristic curves as generated by specific types of equipment.

It is very difficult to analyze existing water hammer conditions or properly design elimination equipment without the use of a good time-pressure recorder. To solve and eliminate water hammer complaints, received from water customers, many water works keep a time-pressure recorder for such investigations only.

Air Chambers

There has been much controversy concerning the merits and demerits of air chambers to suppress destructive surge in water lines. Where properly designed and operated the air cushion is hard to beat. Present formulas for them are so unsatisfactory that some of the most skilled designers readily admit that they make a shrewd guess as to size of air chamber,

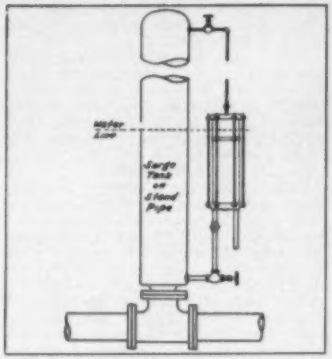


Fig. 6—Automatic Air-Water Volume Control Installed in Surge Tank.—Nu-Matic Co.

(Diagramatic illustration of principles; not actual design.)

then with "trial-and-error" methods arrived at the proper size by the water hammer theory. Experiments show that improperly designed air chambers may actually increase water hammer intensity.

The most common complaint against air chambers is that they continually become water-logged and thus can not function. In the past, for many locations, maintaining proper air-water ratios has been a difficult problem. The Nu-Matic Co. manufactures an air-water volume control, as shown in Fig. 6, which will automatically and constantly maintain correct amount of air in the surge tank without use of any outside power source, other than the water pressure in the water main. As presently designed it ordinarily is used for pressures up to 100 psi, but has been satisfactorily used for 150 psi. maximum.

The conventional air chamber functions by supplying water to the water main in gradually decreasing quantities after the pump has stopped, causing a gradual reduction in the velocity in the line, being similar in design to Fig. 6 with throat and main size being equal.

Theoretically, it is there to force water into the line when the pump shuts down or, at least, to hold the pressure at the discharge comparatively close to the static head. In doing this, it creates in the line a very definite steep grade line. In fact, the grade line is practically vertical with the result that any check valve placed at the discharge of a pump will slam quickly to its seat unless it is very heavily spring loaded. This condition also exists with hydropneumatic pump installations.

The conventional air chamber, in many instances, not only does not eliminate check valve slam, but introduces new conditions which cause check valve failure.

Rensselaer Check Valve

The ordinary type of swing check valve has been one of the worst offenders in creating slam noise. In many instances slam has broken the clapper. Check valves are available which operate silently, but this feature is not a guarantee that all destructive water surge has been eliminated.

With experience gained from many installations, the Rensselaer Valve Co. has used successfully for water hammer elimination their "Quiet Closing" check valve, as shown in Fig. 7, in connection with the air chamber assembly shown in Fig. 8, and the design data shown in Table 1.

TABLE 1

Air Chamber Design data for Tank and Connections Shown in Figure 8.

For discharge lines up to 20,000 feet in length. Maximum velocity 8 feet per second.				
Size of tank (diameter)	18"	24"	24"	36"
(height)	10'	13'	12'	16'
Size of connection (A)	4"	4"	6"	6"
Diam. Discharge line (Max.)	12"	12"	24"	24"
Static head (Max.)	200'	500'	200'	500'

Data from drawing K-3 by Rensselaer Valve Co.

Assuming that the suggested sizes of tanks and connections in Table 1 are approximately correct, then the proper sizes of tanks and connections (A) for other water main diameters would be as given in Table 2.

The solution of this assembly is to place in the line (connecting the air chamber to the main) a check valve permitting flow into the air chamber but not out of it. Around this check valve is installed a small equalizing line, or bypass, shown as 1-inch size. The purpose of this line around the check is to equalize the pressure between

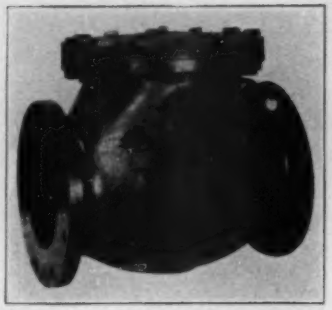


Fig. 7—"Quiet Closing" Check Valve—Rensselaer

TABLE 2

Air Chamber Design Data

(For Various Size Tanks)

Diameter of main	Size Connection (A)	Volume of tank, Cu. Ft. (For 200 Ft. Max. Static head)	Volume of tank, Cu. Ft. (For 500 Ft. Max. Static head)
8"	3"	12	20
12"	4"	18	38
18"	5"	27	70
24"	6"	38	115
30"	7"	48	160
36"	8"	60	-----
48"	10"	80	-----

The ratio of height of tank to diameter should range from approximately 6:1 for the smaller tanks to about 4:1 for the largest. For 30 in. water main the bypass should be about 2 in. diameter and 3 in. for the 48 in. main.

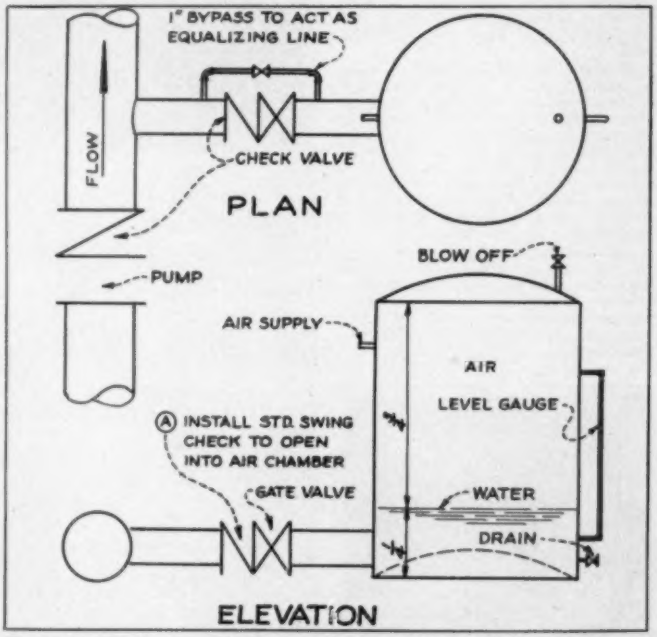


Fig. 8—Air Chamber Assembly for Surge Suppression in Centrifugal Pump Operation (While pump is running, air chamber floats on line absorbing surges. On shut down, pressure at pump discharge drops; compressed air, which is under pumping head, is prevented from slamming check valve at pump discharge to its seat by check valve "A." The return wave of the surge passes through check valve "A," into air chamber, where it is absorbed.)

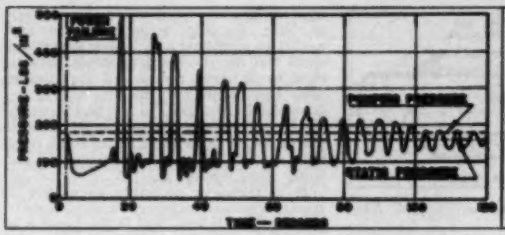


Fig. 9—Pressure Surges Without Surge Suppressor

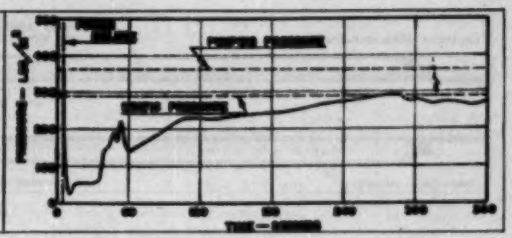


Fig. 10—Pressure Surge in Same Line with Pelton Surge Suppressor Installed

(Typical and actual power failure time-pressure chart. Power failure was on 3000 gpm. pump; 175 psi. static head; pipe line 18,725 ft. of 20-in. steel pipe.)

the air chamber and the main after the pump is shut down. A first-quality non-chattering type of gate valve should be used.

Too large a by-pass line may cause trouble resulting in check valve slam. The size of opening, in the by-pass valve, must be adjusted by trial-and-error, utilizing time-pressure graphs, until no slam occurs in the main check valve when pump operation ceases.

Through the action of the lever arm and spring, the check valve flap is on its seat at the instant the water column in the discharge line comes to rest on pump shut-down; thus, slam is eliminated.

On an installation involving a pipe line laid on a flat grade line, under comparatively low head, of considerable length and with relatively high pipe line velocity, the period in which the column of water comes to rest is appreciable, possibly a matter of several seconds. Since the flap does not seat until the water column in the discharge line comes to rest, the check valve would be closing comparatively slowly but quietly.

Now consider an installation involving a steep gradient with relatively low pipe line velocity. Such an installation would be one in which the pump is placed at the foot of a tower tank or near a hydro-pneumatic installation, or comparatively close thereto. On such a hook-up, the column in the discharge line woauld come to rest quickly on pump shutdown and the flap would, therefore, have to be seated quitckly to eliminate slam.

Another type of installation involving quick closure would be one including two or more pumps discharging into a common manifold. With two or more of the pumps operating, if one is shut down, the return flow to the shut down pump would be practically instantaneous and the flap of the valve would, of necessity, have to close instantly if slam is to be eliminated.

To take care of all these conditions check valve spring tensions must be varied. In the case of the long flat grade line a relatively light spring would do a perfect job. In the case of the steep grade line a heavy spring tension is necessary. As a matter of fact, instances have been found where it was necessary to use two springs, one on either side of the valve to assure quiet closure.

The lever and spring check valve does not eliminate the pipe line surge. It eliminates the danger of severe slam that so often results in broken valve clappers, pipe lines, and fittings. The addition of the air chamber eliminates any surge.

With the check valve in the line between the surge chamber and the main, the slamming effect of the surge chamber is eliminated and the main check valve is able to close normally without slam. The column in the discharge line comes to rest, then with return flow the effect of a building up of pressure is secured. Since the main check valve is closed, the only direction this building up of pressure or surge can move is through the check valve leading into the air chamber where it is absorbed by the surge chamber air cushion. In absorbing this return flow, or surge, there is always an appreciable build-up of pressure. At this point, in the operating cycle, the equalizing line around the check valve functions. It equalizes the pressure between the air chamber and the main, placing them both at static pressure.

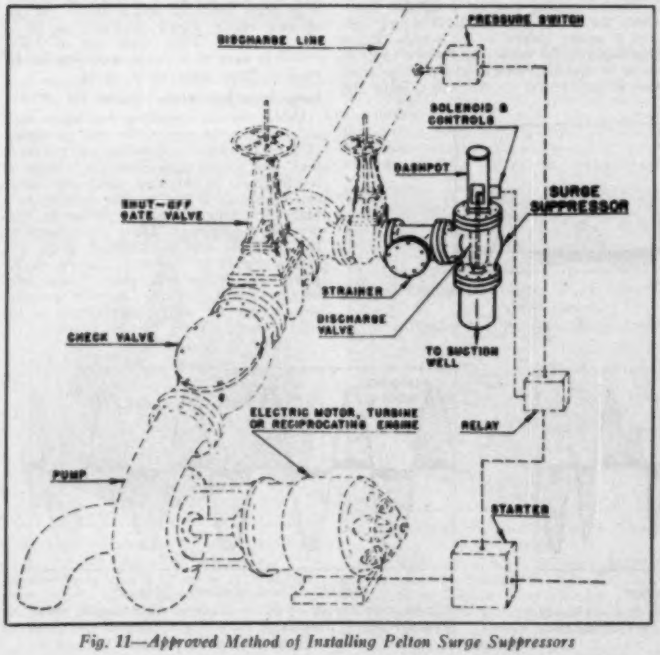


Fig. 11—Approved Method of Installing Pelton Surge Suppressors

Surges in Pipe Lines

The following description of common surges, and their elimination, in pipelines is very general. In actual practice each installation must be carefully studied and the prevention of surge determined by the profile of the pipe line, characteristics of the pump, quantity of water pumped, size and length of pipeline, type and location of air valves, and type of check and altitude valves. There are also many other factors which will influence surge control such as variations in grid system, branch lines, etc. Existing surge is best checked with the aid of time-pressure graphs.

Water hammer is usually caused either by a moving water column striking a closed valve, or a moving water column coming in contact with another water column. The moving water column usually strikes a closed valve in one of the following ways: On starting up a deep well pump, the water column comes in contact with the check valve which is closed because of the static head, or on shutdown of the pumps, the water column returns and strikes the closed check valve.

On Starting Deep Well Pumps

In a deep well pump installation it is the usual practice to employ a check valve to prevent draining of the pipeline on shutdown of the pumps. An air valve is usually installed on the pump side of the check valve to prevent a vacuum in the tubing.

On starting up the deep well pump, it is frequently the case that the water attains a high velocity in the short distance which

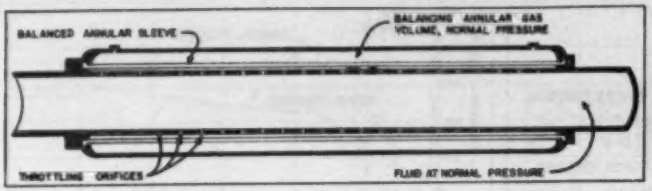


Fig. 12—Fluid Dynamic Desurger—A Conventionalized Cross-Section Showing Basic Through-Line Design Principle

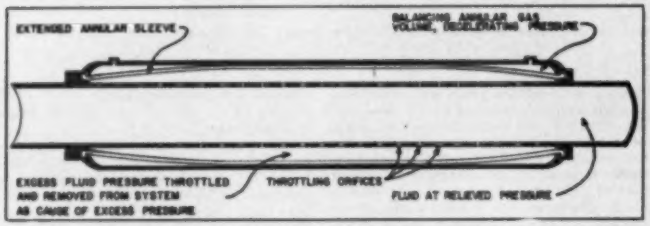

EXTENDED ANNULAR SLEEVE
BALANCING ANNULAR GAS VOLUME, (ACCELERATING PRESSURE
EXCESS FLUID PRESSURE THROTTLED AND REMOVED FROM SYSTEM AS CAUSE OF EXCESS PRESSURE
THROTTLING ORIFICES
FLUID AT RELIEVED PRESSURE

Fig. 13—Fluid Dynamic Desurger—Position of Annular Sleeve When Absorbing Water Hammer Shock

it travels from the suction side of the pump to the check valve.

If the ordinary type of air valve is employed on the pump side of the check valve, the air will escape from the line as the water approaches the check valve and will snap shut when the water reaches it. The water will then strike the closed check valve and create a surge which will be oscillated the length of the pipeline on both sides of the check valve.

A swing-type air valve may be employed which will trap air in the pipeline and thus cushion the contact of the moving water column and the closed check valve; often, however, this is undesirable since it puts air in the pipeline and does not completely relieve the surge.

Pelton Air Valve

To handle situations of the foregoing nature, the Pelton Automatic Slow Closing Air Valve, manufactured by The Pelton Water Wheel Co., has been very successful. This air valve (not illustrated) will open when the check valve closes and upon starting up of the pump it will remain open discharging the air from the pipeline as the water approaches the check valve. When the water reaches the automatic slow-closing air valve, the valve will slowly close thus bypassing most of the water and allow the water to slowly come in contact with the check valve and gradually accelerate the water column beyond the check valve so as to prevent a surge from occurring.

On Shutdown of Pumps

When pumping against a sizeable static head, the greatest problem in surge control is power failure to the pumps. When this happens, for most installations controls must be installed which will provide positive surge control to the water main and equipment, otherwise it would be necessary to have specially designed pumps and motors to withstand a high reverse rotation speed and the check valves would have to close in 30 surge reverses of the pipeline since they would only throttle during approximately the last ⅓ of their stroke. Even with proper control in the check valves, a dangerous surge might result from the retarding actiton of the pumps as the water flows through it.

It is therefore necessary to employ a special apparatus to prevent a surge if there is a high static head and if the pipeline is of considerable length, because the price of a special motor, pump and check valve operating mechanism would be excessive and there would still be the possibility of a dangerous surge developing.

If the pumping head is not too high, a stand pipe may be employed. If the quantity of water being pumped is relatively small, a conventional air chamber may be used. If the head is high and the water quantity moderate to large, a surge suppressor is usually the most economical solution.

Pelton Surge Suppressor

A typical power failure time-pressure water hammer chart is shown in Fig. 9. No surge protective equipment had been provided. The first return wave produced a pressure approximately 2½ times normal operating pressure. Figure 10 shows a typical time-pressure chart after a Pelton Surge Suppressor had been installed. The effectiveness of the surge suppressor is obvious. Figure 11 shows a typical pump station installation of this equipment.

The Pelton surge suppressor is designed to open on the down surge created upon shutdown of the pumps. Being fully open when the water column returns, it bypasses tthe water column, as shown in Fig. 11, preventing a surge. It will then slowly close to prevent pressure from rising in the pipeline. This suppressor will limit the surge to 10 per cent of the pumping head if properly installed and adjusted. It can be used either where electricity is, or is not, available. Both types act as relief valves in case of a surge occurring in the pipeline from some other cause.

Surge From Split Water Column

Under certain operating conditions such as shutdown of pumps, or due to design of the water main system, the water column may split at any appreciable high point in the pipeline. In this case, dangerous surge can be caused if the pipeline extends to a higher elevation than that particular high point in the pipeline. The water column on the reservoir side of that high point will return and strike the water column on the pump side of the high point. Surge may also be caused if the high point in the pipeline, where the water split occurs is the maximum elevation of the pipeline. On

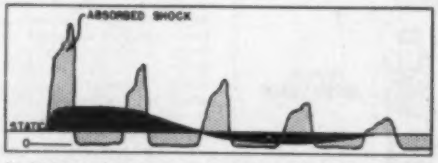


Fig. 14—Fluid Dynamic Desurger—Dark Area Shows Effect of Desurger in Reducing Water Hammer Shock and Surge
(Gravity-flow, tank and pipe line surges with quick closing valve)

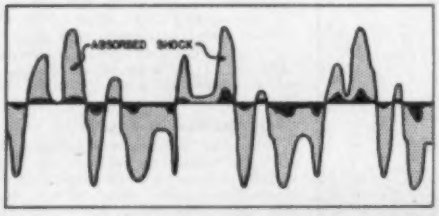


Fig. 15—Fluid Dynamic Desurger
(Shock absorbed by desurger—light versus dark areas—in low cycle high volume surges generated by reciprocating pumps.)

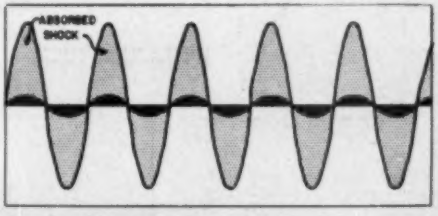


Fig. 16—Fluid Dynamic Desurger
(Dark area shows effect of desurger in reducing water hammer shock from high cycle low volume surger from centrifugal and rotary pumps)

starting up of the pump, the water column on the pump side of the high point will strike the water column on the reservoir side of the high point.

These surges can be diminished by use of an air valve that will trap air in the pipeline and thus cushion the blow of the two columns meeting. It is usually undesirable, however, to have air in the pipeline and it is still possible that under the right circumstances a dangerous surge will still occur.

The Pelton automatic slow closing air valve has been used to prevent this surge and will not trap air in the pipeline. It will bypass the moving water column and then slowly close; thus allowing the two columns to meet gradually and the stationary column to be accelerated slowly.

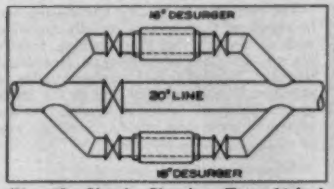


Fig. 17—Sketch Showing Two 16-Inch Fluid Dynamic Desurgers in Parallel to Eliminate Water Hammer in 20-Inch Main.

them back into the line at normal pressures. To meet one of the most difficult applications, it has successfully smoothed out discharge flow from reciprocating pumps of all common types now in use.

Figures 14, 15 and 16 show typical time-pressure waves as generated by gravity flow tank and pipe line surges with quick closing valve, low-cycle high-volume reciprocating pumps, and with high cycle volume centrifugal and rotary pumps all operating both with and without benefit of the Fluidynamic Desurger.

Fig. 18—East Los Angeles; California Water Service Installation of Clayton Pump Control Valves

Fluidynamic Desurger

A new approach to water hammer elimination, and which is proving very successful, is the Fluidynamic Desurger, as manufactured by the Vedco Valve Engineering & Development Co. Conventionalized cross sections of this desurger are shown in Fig. 12 and 13.

The unique design feature of this desurger is that the absorber is an integral part of the water main and operates on the through-flow principle rather than being an appendage located alongside and at right angles to the main. Shock pressures are controlled with this equipment by accumulating them, lopping off their energy, and discharging them back into the line at normal pressures. To meet one of the most difficult applications, it has successfully smoothed out discharge flow from reciprocating pumps of all common types now in use.

This desurger is manufactured for pipe up to 16-inch diameter, but is adaptable for larger sizes by installing parallel units as shown in Fig. 17. For extreme surge conditions it is utilized in a series installation.

With the 16-inch desurgers connected in this manner it is a very simple operation to shut one desurger out for servicing and still have 50 per cent of the desurgers capacity in effect. Another thing, if it is desirable to send a cleaning go-devil through, it does not in any way affect the efficiency of the desurger, nor does this type

Fig. 19—No Slam Check Valve and Surgemaster Control—Cla Val Co.

(Operation is similar to action of "hydraulic door closer," automatically slowing down the valve closing from a fast start to ease the disc to its seat. The opening of the valve is just the reverse—slow to fast.)

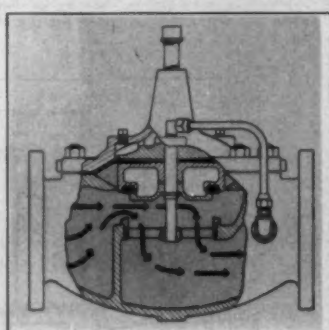


Fig. 20—Open Position—Clayton Pump Control Valve

(Check valve opens when pressure at inlet exceeds discharge pressure. The disc lifts from seat as fluid in cover chamber is expelled into discharge end of valve. The gradual rate of opening prevents sudden starting surges.)

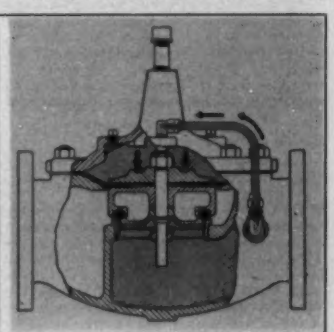


Fig. 21—Closed Position—Clayton Pump Control Valve

(When the discharge pressure exceeds the inlet pressure, fluid from the discharge fills the cover chamber to close the valve. The closing forces thus produced insure an absolutely tight closure.)

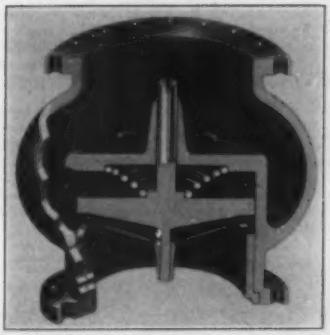


Fig. 22—Williams-Hager Check Valve (Closure occurs when flow is zero.)

The rate of both opening and closing can be regulated to provide a smooth operation without shock. The slow opening feature is desirable when starting centrifugal pumps. This permits starting under a minimum load condititon and as the valve gradually opens, water is admitted to the system without any sudden pressure rise or surge.

Williams-Hager Check Valves

Another check valve having a long successful record in water hammer elimination is the Williams-Hager valve as manufactured by The Williams Gauge Co. and shown in Fig. 22. The spring force enables this valve to close slightly in advance of cessation of flow away from the stopped pump thus preventing reversal of pump and motor. Closure occurs when the flow is zero. The designers of this valve have worked on the theory that water hammer

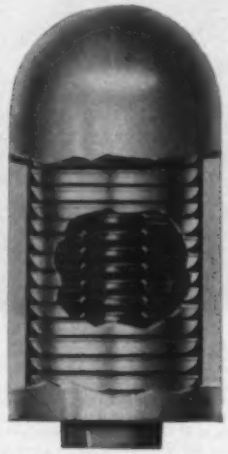


Fig. 23—Wade-Wacor Shokstop (Position of bellows compression unit at time of normal pressure.)

Fig. 24—Wade-Wacor Shokstop (Position of bellows compression unit when absorbing hammer shock.)

of installation prohibit the use of such equipment.

All design technicalities and applications of this desurger have been rather fully explored at the Oklahoma Institute of Technology by John Howard Dawson. Tests show that it will provide a minimum removal of shock of 75 percent at 15 fps. liquid velocity in a pipe line with instantaneous valve closing time.

Cla-Val Check Valve

Another type of check valve which has long been used very successfully in correcting many types of operating difficulties is the Clayton Pump Control Valve, manufactured by the Cla-Val Co. An installation of two of these valves is shown in Fig. 18. This valve was designed to eliminate surge in normal operation. The valve closes while the pump is still running and after the valve has reached the closed position, the pump is stopped by electrical interlocks which are provided between the valve and the pump motor switch.

To eliminate surges and water hammer caused by the stopping of centrifugal pumps the Cla-Val Co. have successfully made many installations of their No-Slam Check Valve, shown in Fig. 19. Interior views in both open and closed positions are shown in Fig. 20 and 21.

in a water line is caused by the sudden stoppage of the flow and the magnitude of water hammer is governed by velocity of flow when flow is stopped and not by psi. operating pressure.

Water Hammer in Buildings

To eliminate water hammer in buildings there are several excellent pieces of equipment available. These are generally of a mechanical-pneumatic design. The location of these suppressors should always be as near the source of trouble as possible. Locating them at bends of pipe is nearly always good practice.

According to size they are very suitable for eliminating shock from such equipment as dishwashers, ice water cabinets, flush valve toilets and urinals, laundry machinery, foot control valves, shower mixing valves, tankless heaters, cookers, mixers, water meters, bottle washers, etc.

Water hammer as encountered in steam heating systems can only be eliminated by proper drainage in which water pockets are not present. It is a generally accepted theory that this type of water hammer or clicking is caused by steam flashes.

Shokstop Air Chamber

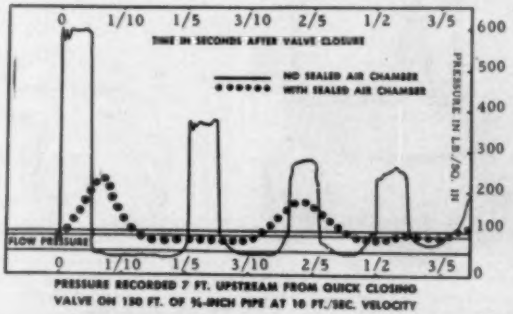
One of the best known surge suppressors for small piping systems is the Wade-Wacor SHOKSTOP Sealed Air Chamber as manufactured by Wade Manufacturing Co. A section view of this suppressor, under normal operating conditions is shown in Fig. 23. Figure 24 shows this suppressor when absorbing surges. This is manufactured for pipes up to 2-inch diameter, but can be used in parallel or series installations for handling extreme situations. It has been thoroughly engineered by Lewis H. Kessler and his associates at the University of Wisconsin, and its limitations are thoroughly understood. Fig. 25 shows a typical water hammer pressure-time diagram both before and after this equipment was installed.

General Silencer

For small piping systems the GENERAL Water Hammer Silencer, manufactured by General Fittings Co., and shown in Fig. 26 is used extensively, especially for building services. It is of the combination mechanical-pneumatic design. The reinforced diaphragm is of neoprene, backed by copper leaf segments, disk and coil spring. It is equipped with adjustable indicator and locknut to insure performance with any normal water pressure. Sizes are available up to 2-inch pipe. It may be used on either hot or cold water lines.

R. S. Heyden Absorber

The R.S. Heyden Shock absorber, manufactured by the R.S. Products Corp., shown in Fig. 27, is used extensively to eliminate water hammer. This unit operates by using



Courtesy Wade Mfg. Co.

Fig. 25—Typical Water Hammer Pressure-Time Diagram. (Diagram shows amount of destructive force created by repetitious shocks on valves, threads, fittings and pipes in buildings.—Dotted line shows same situation after Wade-Wacor Shokstop was installed.)

Fig. 26—General Water Hammer Silencer (Usually installed in house piping systems.)

air, within rubber balls, as shown in Fig. 28, to cushion the shock from the water. The ball in this unit floats free inside the casting, therefore, there is an even pressure distributiton on all sides. Tests of this suppressor have been made at the University of Minnesota and the University of Pennsylvania. Five sizes of this suppressor are available and two or more units can be utilized for flows greater than 300 gpm.

Mar-Coil Silencer

To eliminate water hammer in hot and cold water lines in buildings the Mar-Coil Silencer as manufactured by Mar-Coil Heater Co., and shown in Fig. 29, is used extensively. A sectional view showing inside construction of this silencer is shown in Fig. 30. This silencer should be placed as close as possible to the valve that hammers. If that is not possible, it may be placed on the bottom of the riser. The silencer is frequently placed on the hot water line from tankless heaters. Often it is placed at the foot of risers to flushometers to eliminate water hammer.

Conclusion

It is not a simple matter to properly design against, or eliminate all water hammer in existing pipe systems, as this article definitely demonstrates. The mathematics of computing water hammer pressure and wave velocity in any given situation is not particularly difficult, but even if one is competent to make such calculations, generally their value is very questionable due to the many assumptions which must be made. A time-pressure graph eliminates many assumptions—they give true answers when competently interpreted. Theoretical calculations have maximum value in designing for required time-of-closing of valves, before they are installed.

No surge suppressor is known which will operate at any stated efficiency under varying operating conditions. The size to be used is generally determined by the rate of flow in the pipe involved. The efficiency decreases as this rate of flow is approached or exceeded.

Equipment Manufacturers

BACHARACH——Bacharach Industrial Inst. Co., 700 Bennett St., Pittsburgh 8, Pa.

CLAVAL——Cla-Val Co., P. O. Box 949, 1600 Orange St., Alhambra, Calif.

ELECTRO PRESSUREGRAPH——Electro Products Lab. Inc., 4501 N. Ravenswood Ave., Chicago 40, Ill.

Fig. 27—R-S Heyden Liquid Shock Absorber

ESTERLINE ANGUS——The Esterline-Angus Co. Inc., P. O. Box 596, Indianapolis 6, Ind.

FLUIDYNAMIC——Vesco Valve & Engineering & Development Co., 130 N. Boston St., Tulsa 6, Okla.

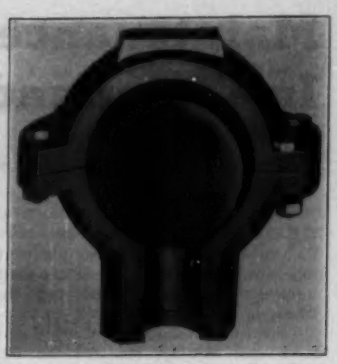


Fig. 28—R-S Heyden Liquid Shock Absorber

(Sectional view showing rubber cushion encased in spherical chamber. This cushion, with an air space in the center, absorbs the shock to which it is subjected.)

GENERAL——General Fittings Co., 123 Georgia Ave., Providence 5, R. I.

MAR-COIL——Mar-Coil Heater Co., 2000 Paterson Plank Rd., Union City, N. J.

NU-MATIC——Nu-Matic Company, P. O. Box 949, 1600 Orange St., Alhambra, Calif.

PELTON——The Pelton Water Wheel Co., 19th & Alabama Streets, San Francisco 10, Calif.

R-S HEYDEN——R-S Products Corp., 4530 Germantown Ave., Philadelphia 44, Pa.

SHOKSTOP——Wade Manufacturing Co., Elgin, Ill.

WILLIAMS HAGER——The Williams Gauge Co., 1620 Pennsylvania Ave., Pittsburgh 33, Pa.

Fig. 29—External View of Mar-Coil Silencer *Fig. 30—Sectional View of Mar-Coil Silencer*

(These units are generally used with both hot and cold water lines in buildings.)

Maintenance of Electrical Equipment In Water and Sewage Works*

by A. R. WALKER, *Application Engineer, Westinghouse Electric Corp., Atlanta, Ga.*

MOTORS, generators, and controls are designed to perform indefinitely, year in and year out with minimum attention and interruption. They do just that.

New machines purchased years ago have now become old and trusted. They are now grown to manhood and practically able to take care of themselves. You may think they will click through hell and high water, but they won't, because, without maintenance, plain simple maintenance—they will fail.

It behooves all water and sewage works operators to give more thought to this maintenance problem and to make regular inspection and periodic checks—it pays dividends.

The time to make inspections and periodic checks is before, rather than after, failure. In my organization, we definitely know this. Each year we receive thousands of sick motors. This same thing is true with all the repair shops which go to make up one national network of service facilities for these sick items of electrical apparatus. You as individual operators, perhaps do not fully realize the magnitude of this Electrical Clinic.

Operation of this Coast-to-Coast Electrical Clinic permits us to answer a question which is vital to every maintenance man. What are the principal causes of motor failure? They number just four—and all four of them are so simple, so obvious that your first reaction when you hear them may be one of impatience. You may ask, "why take up the time with such elementary material?"

But, this figure is much too important to be ignored, since 90 percent of all motor failures are due to obvious causes, and it's time we all began paying more attention to the obvious. So here are the four causes of motor failure!

Cause No. 1 Is Dirt!

Dirt is matter out of place. It can be ordinary under-foot dirt that rises into the air when workers walk and trucks trundle by your plant. It can be powdered chemicals swept into the air from a nearby processing plant. But white or black, when it's blown out of place it rates as dirt.

Dirt in any form can be deadly to a motor. It can plug ventilating spaces, interfering with proper cooling. It can glaze the faces of commutator brushes, resulting in harmful sparking. It can abrade sliprings, multiplying wear and blocking the full passage of current. It can blanket windings, interfering with their proper heat radiation and causing dangerous temperature rises.

If metallic particles are present, dirt can build up into a hazard of shorting or grounding. Eventually, if not corrected, it can cause complete motor breakdown.

These conditions, of course, should never be allowed to occur, and they won't occur, if precautions familiar to all of us are really taken. Let's review what they are.

In the case of totally-enclosed motors, anti-dirt precautions boil down to the periodic use of a wrench. At regular intervals all exposed joints should be tightened; all exposed joints in the motor frame; all exposed joints in the motor brackets.

In the case of open-type motors, good maintenance includes additional anti-dust precautions. Care should be taken, for instance, to make sure that dirt is kept out of bearings and that oil filler caps are always closed. Care should be taken that dust seals and gaskets are in good condition. If they're worn, be sure to replace them.

Wipe Off and Blow Out Dirt!

Be sure, also to have plenty of clean rags on hand, and at regular inspection intervals, see that they go to work . . . wiping off motor housings . . . cleaning commutators and sliprings . . . removing dust from the wound section. For all of these wiping operations it is important to use RAGS . . . not waste. Waste contains lint which adheres to the surface it contacts.

Here's another anti-dust measure for the motor that isn't totally-enclosed. Once a month, or more often, if necessary, blow out the windings with compressed air at a pressure of between 30 and 50 pounds. Make sure that pressure isn't greater than that or the blast may loosen the insulation and blow dirt under it.

Sometimes the blowing out of a motor is impractical because high fidelity operations nearby might be impaired by the displaced dirt. In that event—air suction rather than blowing should be the method employed.

Solvents To Use

Sometimes neither blowing nor suction will adequately clean out a motor. If the accumulated dirt has remained long enough to unite with grease or oil, it tends to stick and stick so stubbornly that a special solvent may be required to remove it. Three principal types of solvent are in general use for this purpose.

Of these three different types, the petroleum distillates have the least corrosive action on insulation varnishes. For that reason they're to be preferred if the dirt doesn't prove too stubborn. If it does, a mixture is nonflammable, although its vapors in proper combination with air may be explosive.

In extreme cases, straight carbon tetrachloride may be necessary, but in that event plant safety rules regarding its handling should be closely observed. The fumes of this solvent can be poisonous!

Plant safety rules should also be followed closely in the handling of petroleum distillates. Workers should be warned particularly not to cause accidental sparks during the washing process. If such precautions seem a troublesome nuisance, remember that there's always one sure way to avoid them. Don't let a dusty motor go neglected too long. If the dirt is removed before it has had a chance to gum up through union with oil and moisture, solvents won't prove necessary.

There are not many things more nasty to handle than an extremely dirty motor. After removing a dirty motor it's a pleasure to replace with a clean one. This question of dirt can't be over emphasized.

Cause No. 2 Is Moisture

Moisture, like dirt, can be deadly to a motor. It soaks and softens windings until the insulation will no longer hold the voltage. Once inside the motor, it unites with any dirt present to form a sticky mass.

*Presented before the Georgia Water and Sewage School, and here published by permission.

Moisture also absorbs acid fumes and alkali fumes present in the air. Fumes which may quickly change it from mere moisture to an actively destructive agent.

Here, again, are conditions that shouldn't occur if maintenance is really doing the obvious things we all know about. Anti-moisture precautions are especially simple.

Open motors should always be guarded against the accidental intrusion of water from drip or splatter. Stand-by motors should be run a little at least once a week to guard against moisture condensation during periods of idleness. Large and expensive standby motors often have space heaters installed to keep them dry during idle periods.

Before motor windings are blown out, a check should always be made to make sure water hasn't condensed in the air line, coming from the compressor.

Cause No. 3 Is Friction

Anti-friction precautions are simple and easy to take. Let's review them, first, as they apply to motors with sleeve bearings. In this type of bearing oil adheres to the shaft and is dragged along by rotation. In this way, a lubricating film is formed that prevents friction if certain precautions are observed.

Use the right oil! Use it in the right quantities at the right intervals following closely the lubricating instructions of the manufacturer.

Oiling Don'ts

Don't add new oil while the motor is running! Here's why. When the motor is running, a certain amount of lubricant rides the ring over the oil level. As a result you may be fooled into adding too much oil—and if you do that—unless your motor has the special protection of a sealed sleeve bearing—excess oil is almost sure to escape from where it belongs.

Once this oil has escaped, the damage it can do is serious. It can deteriorate the mica insulating segments between commutator bars. It can foul the commutator bars themselves. It can soak windings to the point where rewinding may be the only way to prevent burnout or breakdown. It can "gum up the works" in general.

Ball Bearings

Now review the anti-friction precautions needed for motors with ball bearings. Make sure the inner race is tight enough on the shaft to rotate with it but not so tight as to cause frictional distortion.

Another important precaution involves correct greasing. Apply the right greases, in the right quantities, in the right way. Follow exactly the greasing instructions of your manufacturer. And whatever you do don't over-grease. Excess grease promotes friction and along with it, heat.

There are probably more motor failures caused by too much lubrication than any other single cause. It is better to take chances with too little oil than too much.

Cause No. 4 Is Vibration

If excessive vibration is permitted to develop in a motor, parts can be shaken loose—electrical connections can be broken—portions of the metallic structure crystallized—frictional wear of every kind greatly increased!

To avoid these consequences of vibration, a few simple checks should be made—and made regularly—check frequently for misalignment. Foundation settling, heavy floor loading, excessive bearing wear—any or all of these may be causing vibration through misalignment.

Check to see if vibration in the driven machine is being transmitted to the motor; if excessive belt or chain tension may be at fault; or, if the trouble may lie in the push-apart effect inherent in spur gears.

Check, too, for the possibility of motor shaft oscillation resulting from a loose bearing, and don't forget the possibility that motor mounting bolts may have worked loose. Check them, too.

To summarize, 90 percent of all motor failures are due to just four causes . . . all of them simple, all of them thoroughly familiar to you, all of them preventable.

To make sure that your motors and generators stand up under today's loads, guarantee them four freedoms:

1. FREEDOM FROM DIRT!
2. FREEDOM FROM MOISTURE!
3. FREEDOM FROM FRICTION!
4. FREEDOM FROM VIBRATION!

It isn't *what* we know that counts. It's what we do about what we know. So let's swing into action on the simple, obvious things that keep motors humming.

Now, we have control. Manual starters . . . magnetic starters . . . drum controllers . . . speed regulating rheostats . . . contactors . . . relays . . . and circuit breakers!

Maintenance of Controls

All of these controls have one thing in common: They all need maintenance. The kind of maintenance they need breaks down into a series of ten simple checks.

Maintenance Check No. 1

Make sure all connections are tight!

Loose connections can cause trouble in practically any form of electric control. Unless the screws or bolts that hold them in place are tight at all times—here's what happens.

The loose contact surface offers high resistance to the passage of current and consequently develops heat. This heat, in turn causes increased oxidation of the copper. Since copper oxide isn't a good electrical conductor, still further increase in resistance and heating results. Continuance of this vicious circle can melt the contacts and deteriorate the entire contact assembly.

While all control connections should be tested for tightness here are some that merit a double check. If connections to overload relay heaters get loose, and are permitted to stay that way local heating results, and can affect the whole calibration of the relay or even destroy it. Tightness testing is also doubly important in the case of a rheostat.

After an overload relay heater has been installed and put into operation, all connections should be checked at least twice to make sure they remain tight under the stimulus of heating. If they loosen, and aren't promptly tightened—burn-out and failure of the controlled equipment can result.

Even in the case of simple manual starters with quick-make and quick-break toggles, tightness testing is important. As a matter of fact, practically no maintenance is involved except tightness testing. But remember—once tight doesn't mean always tight! Changes in temperature, vibration, carelessness, any or all of these can cause connections to loosen again. So if you want your controls to keep controlling, test for tightness periodically!

Maintenance Check No. 2

Make sure all operating parts stay clean.

One common way that they may become dirty is from oil. Unless the control device is specially designed for complete oil immersion, lubricant should never be applied. When oil or grease is put on the bearings of a contactor or relay, it catches dirt. The result is a sticky, gummy accumulation that causes sluggish action of the moving control parts.

It should be remembered, however, that there are certain exceptions to the "no lubricant" rule for electric controls. Control devices completely immersed in oil are specially designed for high-voltage installations or explosive atmospheres or in areas where corrosive fumes are present in the air.

Here's another exception. Drum controllers with sliding copper-to-copper contacts should have their contact parts occasionally lubricated with a thin film of vaseline or light oil. The bearings which support the drum shaft should also be lubricated. On occasions of periodic inspection, either grease or oil should be applied.

Magnetic linestarters are still another exception to the "no lubricant" rule. Magnet sealing surfaces should be occasionally wiped with an oil-moistened cloth—to prevent *noise* and *rust*.

But, by and large, oil and electric control devices don't mix! Lubricant applied to contact bearings causes dirt and dirt causes trouble.

When dirt does accumulate, here's the routine way to remove it.

Periodically blow out the control with clean, dry air under a pressure of from 30 to 50 pounds. If that doesn't suffice, get the job done by wiping or washing with a suitable cleaning fluid.

Maintenance Check No. 3

Make sure the control devices stay dry!

It may become moist from any of several causes—condensation resulting from temperature changes—extremely humid atmospheres—overhead drip—spray.

These can cause grounds in the control device and grounds, in turn, can do all these things: They can cause unexpected starts—prevent normal stopping—eliminate overload protection—impair operation. To prevent such control irregularities, heaters are often installed in the control enclosure. (These needn't be energized except when the control device is idle. In operation the normal heat of resistors and coils does an adequate drying job).

Elimination of moisture from conduits is another good preventive measure. Still another is the semi-annual or quarterly use of paints and varnishes. If the air surrounding a control device is saturated with moisture, or mixed with corrosive gases, apply insulating varnish of the proper characteristic to the coils, and protective paint to the iron parts. These simple anti-moisture precautions are well worth the trouble they take. They help keep controls controlling!

Maintenance Check No. 4

Look for the presence of copper oxide!

This check will probably prove negative, if the contacts of a control device operate often enough. When contacts open and close frequently two factors combine to keep their surfaces bright. First, a mechanical rolling and scrubbing action. Second, the slight burning effect of a normal arc. But these two factors combine to prevent the accumulation of copper oxide only if contact operation is frequent enough. If it isn't, an oxide coating develops which causes high resistance.

The area where this kind of high resistance is most likely to occur is at the point where stationary and movable tips contact. High resistance may also occur, such as any one of the several bolted joints of a contactor.

Find out which of them may be causing a high temperature condition. Then, having found out, open the contactor and disassemble the parts. Then remove oxide film from the surfaces found to be at fault. For the removal job, use either sandpaper or a fine file. Do not use emery cloth!

Maintenance Check No. 5

Inspect contacts for *excessive* roughness.

Note the emphasis on the word "excessive." A moderately rough contact surface is just as good and possibly even better than a perfectly smooth one. So when inspection reveals surfaces no rougher than coarse sandpaper, leave them alone.

It may be, however, that unusual arcing will have developed large projections on certain contacts. In that case, do one of two things.

If the contact hasn't worn down more than a third of its original thickness . . . and if its surface isn't too badly pitted, smooth it off with sandpaper or a fine file.

If the contact point or tip is less than two-thirds of its original thickness, or if it's badly pitted, or if it no longer compresses the spring, replace it with a new one. Contacts should be replaced in pairs or steps. Do not operate with one new one and one worn contact operating as a pair.

Maintenance Check No. 6

Test for normal clearances and free working of moving parts.

At regular intervals operate by hand all contactors and circuit breakers. If you note any binding or undue friction, find the cause and correct it.

Maintenance Check No. 7

Test for firmness of contact pressure.

A small contact with suitable contact pressure will carry more current than a large one with little or no pressure. So make sure that all contact springs are in good condition. If one has been damaged, or if its temper has been lost by exposure to high arcing temperatures, replace it!

Maintenance Check No. 8

Inspect for frayed shunts.

Shunts are generally flexible bands of woven copper strands that carry current from the movable contacts to a stationary stud. If a shunt is unduly bent, some of its strands break, causing additional loading of the remaining strands. Shunts with broken strands should be renewed to prevent overheating. Broken shunts could also cause shorts or grounds. Another reason for inspecting shunts is the possibility of corrosion. In extremely corrosive atmospheres, shunts have been known to fall apart before any warning sign of failure was apparent.

Maintenance Check No. 9

Inspect Thermal Relays for ambient temperatures surrounding their enclosures.

Perhaps your inspection will reveal some newly introduced condition such as new steam pipes just installed. Because it's calibrated to operate at one definite temperature, a thermal relay should be in an area which is at the same temperature as the motor room, that is, unless its heater has been selected to make it operate properly under unusual temperature conditions.

Maintenance Check No. 10

Make sure each control device is operating at rated voltage.

Both overvoltage and undervoltage can impair electrical control. Overvoltage can shorten coil life and cause excessive wear in contactors and relays. Low voltage can cause sluggish action. This means that contact tips may touch but not be forced completely together against spring pressure. The result is overheating and a probable weld together.

Maintenance Check Summary

Let us summarize these ten checks on the maintenance of electrical control.

Keep it tight—clean—dry!
Keep contacts free of copper oxide and moderately smooth.
Keep all moving parts free, contact pressures firm, shunts unfrayed.
Keep ambient temperatures of thermal relays matched.
Keep every control device operating at rated voltage.

If these checks are followed your controls will keep controlling, making and breaking circuits thousands of times a day, dependably playing their part in your operation.

Two Kinds of Maintenance

There are two kinds of maintenance.

1. Preventive maintenance.

2. Regular maintenance.

Preventive maintenance looks to those things which, when taken care of in time makes failures unnecessary.

Ordinary or regular maintenance takes care of the trouble after it happens. *Down time* means trouble from numerous sources. In addition to the actual cost of repairing or replacing the failure, you may have the loss of revenue because of shut down, you have the criticism of disgruntled customers, you have the added cost against not too favorable budgets and many other troubles most of you could mention.

Preventive maintenance would therefore seem to be a "Must," and preventive maintenance involves the following among other things.

1. A definite program of inspection and checking.

2. Education of operators, particularly if new.

3. Keeping of proper records is always helpful.

4. Adequate stock of Renewal Parts.

5. Budgeting of money for required maintenance including overhauls when necessary.

6. Periodic cleaning and varnishing.

7. Regular lubrication schedules.

8. Keeping up with new products, new developments, new methods of maintenance for specific equipment, and other modern devices that may replace old antiquated equipment that has served its turn.

Safety

Although the following comments do not directly apply to maintenance as such they are important to each and every one of you.

Let's play it safe.

You cannot be too safe in working with electrical apparatus. Safety rules should be established if not already available and rigidly enforced. There should be no compromise, since electricity is no respector of persons.

These are some of the things to watch out for:

1. Grounded circuits—all electrical equipment should be properly grounded.

2. Never stand in a damp or wet place when working on electrical circuits. Use dry plank or rubber mat.

3. Use rubber gloves if possible.

4. Safeguard all open circuits or equipment with an enclosure or fence and particularly if high voltage indicates such.

5. Do not attempt to make short cuts. This may prove dangerous.

6. Each operator should know the principles of artificial resuscitation. This may save a life.

7. Have all equipment properly installed and do not tolerate makeshift arrangement. Small saving in initial installation may prove extremely costly later, perhaps the saving of human life.

8. Do not work on equipment unless you are sure the line is dead and proper precautions are made to prevent accidental re-establishment of power.

9. It is desirable although not always possible that maintenance crews work in pairs. In this way, should an accident occur, help is then available.

These points and many others as familiar, should be carefully considered in view of saving a human life that could perhaps be your own as well as the protection to the apparatus.

New Outlet for "Slightly Bent" Fire Hydrants

The following clipping come to us from "Bill" Wise, Sup't. at Greenwood, S.C., who says: "This item must refer to our neighbor city of Greenville, S.C., since this kind of request could only happen to our friend Johnnie Hawkins, Sup't. at Greenville. Undoubtedly this request will give him the idea that he should now start a public relations program pointed up in the direction of 'The Pups of Greenville.'"

USED FIRE HYDRANT SOUGHT

Greenville—(AP)—A Greenville resident asked the City Water Works today to help put her dog in top canine style.

She wanted to buy a worn-out fire hydrant for her dog's yard. Did the department have any?

Not at the moment, but officials promised to let her know when one became available.

Ed. Note: This is a new one, but maybe it's a better market for discarded hydrant barrels than the junk dealers. If the idea makes the owners of the pups of water customers happy there's a double reason for promoting this new outlet for cracked or otherwise discarded hydrant barrels.

This writer has often wanted a "slightly bent" hydrant to plant in front of his home. Most effective known method of insuring a place to park in front of one's own house.

Trap-Door Funnel
(For Discarded Sludge Samples)

Disposal of Sewage Sludge Samples*

In some sewage laboratories disposal of the various sludge samples is a nuisance.

Where proper means are not available these samples may be dumped into the sink or the toilet or even on the nearby grounds. When a trap door is conveniently located near the laboratory a much more satisfactory and less obnoxious procedure is afforded by the simple device illustrated in the accompanying picture. It consists essentially of a large metal funnel, having a wide mouth about 7½ inches in diameter, an overall height of 13½ inches and a pipe stem of 4 inches outside diameter. The stem is threaded through the trap door of the sewer conduit into which the sludges are dumped directly.

The device shown here has proved a solution to the messy job of disposing of sludge and similar samples.

*Contributed by Ralph W. Frey, Chemist, Washington Suburban Sanitary Comm., Hyattsville, Md.

Are You a Square Peg? If So Do Something About It

"There is nothing as important to a man than that he select for his life's work some line with which he is entirely happy. Enjoyment in one's daily work should be the main pleasure in life. Under such circumstances, regardless of natural ability, he is likely to advance further than otherwise."—*Dr. Roger Adams* in *The Chemist.*

Propeller Type Meters For Main Line Metering

by JAMES M. MONTGOMERY, *Consulting Engineer, Pasadena, Calif.*

THE principle of the current meter has been used as a primary metering element for the measurement of stream flows for many years. Since 1924 this same current meter principle has been applied as a primary element for the measurement of main line flows by the Sparling Meter Co., Los Angeles, California, and since 1944 by Builders-Providence, Inc., of Providence, R.I. This type of meter has proven itself well suited for this purpose.

Characteristics

The current metering principle is well adapted for main line measurement as the action of the propeller is solely dependent upon the velocity of the flow in the line. The pressure requirement is only that which will always maintain a full pipe of water. The loss of pressure caused by the metering element in sizes 6-in. and larger does not exceed 6 inches of water at normal maximum pipe velocity.

Continued accuracy of the current type meter is dependent chiefly upon maintaining a clean metering section, keeping the propeller free from incrustation and preventing solids, which might damage the propeller, from entering the pipe line. The plastic propeller has proven itself well suited for this purpose, as it is practically inert and will resist both corrosion and electrolytic action. In order to maintain a uniform meter section the propeller assembly may be mounted either in a cast iron, steel, or bronze tube with a liner and straightening vanes.

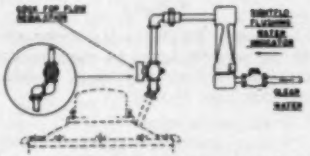


Fig. 1—Continuous Flushing System with Builders Sightflo Indicator

Meter Features

Propeller type meters as manufactured by the Sparling Meter Co., and by Builders-Providence, Inc., have high accuracy over wide range, measuring within plus or minus 2 per cent of actual flow from about 10 per cent to 100 per cent rated capacity. Both manufacturers' meters have an "open upper limit" or temporary overload range, where the meters will continue to register with good accuracy at rates up to at least 150 per cent of rated capacity. Both the Sparling and the Builders meters are self-contained and self-operated, requiring no mercury, pressure piping or electrical connections; they are as easy to install as a valve or fitting with no adjustments required in the field.

One feature of the Builders Propeloflo Meter is the Venturi design for increased velocity at the point where the fluid acts on the propeller.

Both types of meters can be used with secondary instruments, either cable-driven or electrically-operated totalizers only, totalizer-recorders or totalizer-indicator-recorders for nearby or remote location, when so specified. They may also be used in conjunction with electric alarm registers, where measurement of a predetermined quantity of liquid is required.

With the Builders Propeloflo Meter a continuous flushing system is recommended when metering the flow of liquids containing gritty materials or heavy concentration of solids. This system introduces a small continuous back flow of clear water into the propeller hub, thus preventing the solids-bearing liquid from reaching the propeller shaft bearing. The Builders Sightflo Indicator in this system gives a visual indication that the back flow is adequate and is properly maintained. (See Fig. 1)

The Propeller

The propeller type meter, as illustrated in Figs. 2 and 3, is made up of a 6-blade propeller, approximately 8/10 of the internal pipe diameter mounted transversely in the center of the pipe. The propeller is made of plastic material, having a specific gravity of approximately 1, and is suitable for use in either cold water or hot water, up to 300° F. For special liquids the plastic propeller may be replaced by an aluminum propeller, or stainless steel propeller, depending upon requirements. The propeller, when made of plastic, practically displaces its own weight in water and is mounted on ball bear-

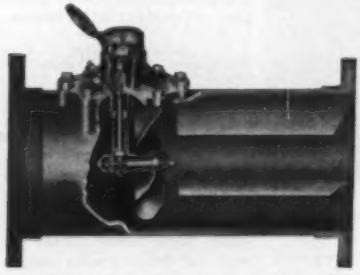


Fig. 2—Cutaway View of Sparling Propeller Meter
(Note the flow straightening vanes)

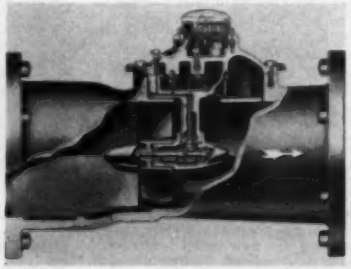


Fig. 3—Cutaway View of Builders Propeloflo Meter
(Note the Venturi design and streamlined nose of propeller mechanism)

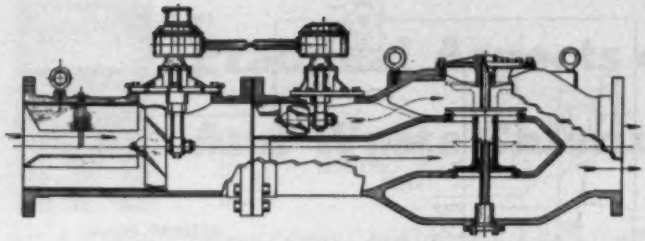


Fig. 4—Section Through Propeller-Type Compound Meter
(Note valve which closes on low flows to cause entire flow to pass through small meter.)

ings, which allow it to rotate freely in the stream of water.

Installation

The metering element may be installed directly on an existing pipe line by means of a saddle either bolted or welded directly on the main. In such installations it is important that the inside diameter of the pipe be accurately determined and the meter properly centered. In all installations the meterhead may be removed from the pipe line very quickly and easily, and it is normally good practice to make a yearly inspection.

In selecting the proper location for the metering element it should be kept in mind that a normal flow of water, free from either spiraling or jet action, is required for accurate results. The spiraling effect which may be caused in the flow of water passing through a series of elbows, can be largely corrected by installing straightening vanes in the line preceding the meter.

Various forms of such vanes are in use, but a very simple and effective correction may be made by the installation of 3-vanes, each approximately ⅓ the pipe diameter, and 2½ pipe diameters long, set at 120 degrees to each other in the pipe. These vanes will not eliminate a disturbance caused by a partially opened gate valve, but are effective for double elbows or other standard fittings, and with such vanes the manufacturers state that the meter element may be installed with but two pipe diameters of straight approach. However, when possible, a longer section of straight approach is desirable.

A straight run of one pipe diameter downstream from the meter is normally sufficient for all installations. Unless a straight run of at least ten pipe diameters is available ahead of the meter, it is always good practice to use the straightening vanes. When the metering element is installed complete with either a flange or bell and spigot tube, straightening vanes are mounted directly inside this metering section to constitute a complete unit, ready for installation.

Fig. 5—Typical Sparling Indicator-Recorder of the Mercury Governor Type

The metering element may be installed in either a vertical or horizontal pipe and it may be mounted on either the suction or discharge side of a centrifugal pump.

Standard Specifications

The American Water Works Association has published standard specifications for cold water meters—current type, propeller-driven—known as No. 7M5-T. These cover general description, capacity, size, design, connections, operating mechanism, and notes of special importance.

Calibration

Experiments and experience have shown that a propeller will rotate in direct proportion to the velocity of water in a pipe at all flows above an approximate pipe velocity of ½ linear foot per second. The index, or number of cubic feet passing through the pipe for each turn of the meter shaft, is determined from volumetric tests. From this index proper gears are furnished for direct totalization of the flow.

Compound Design

Fig. 4 is a sectional illustration of a compound meter suitable for use where an extremely wide range of flow measurement is required. This is offered by the Sparling Meter Co., of Los Angeles, and has a range of 150:1. A compound unit consists chiefly of two propeller type meters working in series through a pair of ratchet clutches, allowing the meter revolving at the highest speed to drive the totalizer-register. On a very low flow the large meter will under-register, and thus allow the small meter to drive the totalizer. As the flow increases a pipe velocity is

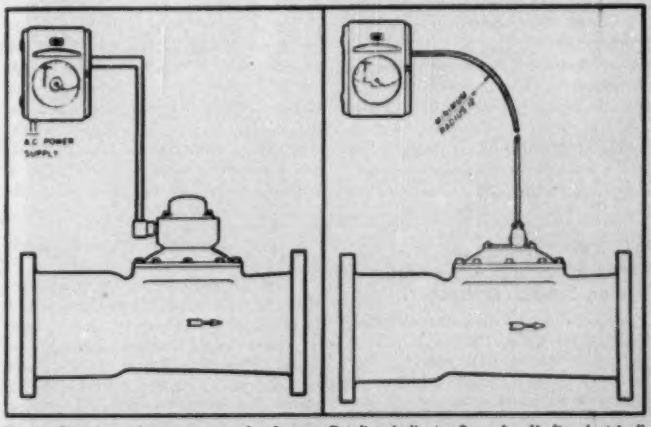


Fig. 6—Diagrams of Arrangement for Remote Totalizer-Indicator-Recorder (Left—electrically operated; Right—cable operated)

reached where the large meter has come in step and the small meter is operating at a high capacity. At this point the pressure loss caused by the small meter operating on the differential area of the compounding valve forces the valve to lift itself and allow the higher flow to by-pass the small meter.

Although the minimum flow is considerably above that of the standard domestic *compound* meter, it is well adapted for main line measurement as the pressure loss caused by the entire unit does not normally exceed 2 pounds at maximum flow.

Indicating and Recording Elements

A rate-of-flow indicating and recording instrument may be used in conjunction with the straight totalizing primary element. The primary step of a curent type meter is direct totalization. If the rate-of-flow indication is desired it must be obtained through a secondary step normally involving either a governor bowl or a friction plate revolving at a constant speed with a follower locating itself on the plate by impulses from the primary element.

Figure 5 illustrates the recording instrument involving a governor bowl which is driven either mechanically up to 15 feet from the metering element, or electrically to any distance required. The governor bowl consists chiefly of a float riding in the center of a mercury well. As the governor revolves, the mercury, through centrifugal force, finds its way through a small needle-valve to the outer chamber of the bowl, allowing the float in the center to have a rising and falling action in proportion to the revolving speed of the bowl. This type of governor is effective over approximately a 6-to-1 range and is extremely simple and well suited for normal flow measurement.

A recording instrument utilizing the revolving friction plate, with a follower locating itself by impulses from the metering element, as mentioned above, produces a straight line of rate indication over approximately 25-to-1 range and is well suited for recording flows of main distribution or consumption lines.

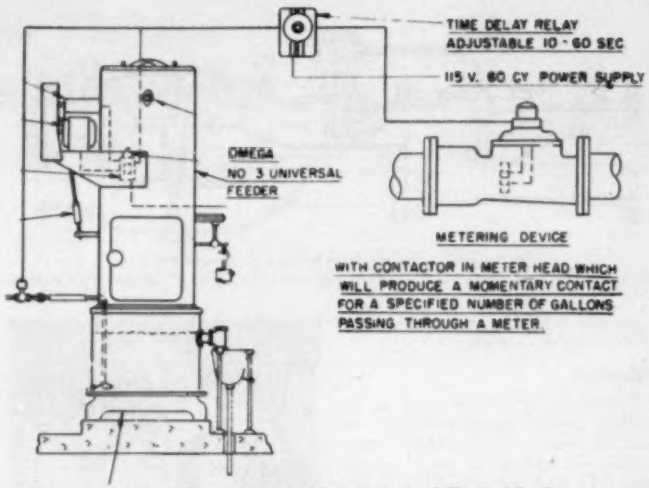


Fig. 7—Propeloflo Meter Used to Pace Proportional Chemical Feeding

Recorders can be adapted to show the combined flows of two or more pipe lines and combinations may be furnished showing the net total of several lines where the flow of any one pipe may be in either forward or reverse direction.

Electrically operated totalizer-indicator-recorders make possible the transmission of liquid flow metering information over any distance (See Fig. 6). A simple two-wire circuit carries the impulse from a transmitter at the Builders Propeloflo meter to the remotely located receiving instrument. Similar remote operation is available for the Sparling meter.

Flexible cable operated totalizer-indicator-recorders (See Fig. 6) permit transmission of liquid flow metering information to any point within a 15 ft. radius of the propeller type meter. In the case of the Builders Propeloflo meter, the flexible cable is connected to the meter either by a straight-type adapter plate or by a right angle take-off. At the receiving instrument, the connection is made through a coupling unit which can be positioned for straight line approach of the cable to the instrument.

Application in Chemical Feed Control

Automatic control of chemical feeders, by either mechanical or electrical means, is readily obtainable from a current meter element as the shaft of the meter is revolving in direct proportion to the flow and considerable load may be applied without affecting the rotating speed of the propeller.

If given the periodic inspection required by any primary metering element, the characteristic of low pressure loss and accuracy over a wide range of flow allows the principle of the current meter to fill an important part in the water works field.

The propeller-type meter is not suitable for measuring raw sewage and is not generally recommended for measurement of a sewage effluent unless the effluent has passed through a filter bed. When installing such meters on raw water gravity lines, care must also be taken to provide screens at the inlet structure to prevent excessive algae or weeds from passing down the pipe and fouling the meter propeller.

N. Y. State Holding Water & Sewage Operator Training Schools in April

The Municipal Training Institute in cooperation with the N.Y. State Dept. of Health will conduct two training schools in Albany during the week of April 23rd.

Water Operators School—April 23-25.

Sewage Operators School—April 26-28.

These schools are being held particularly for Grade III operators and those seeking certification as Grade III operators. However operators in higher brackets will find these schools of value as refresher courses and a means of keeping up with the newest developments in water and sewage works operation and maintenance.

The Conference of Mayors of N.Y. State in issuing the notice concerning these schools point out that expenses incurred through attendance by plant operators constitute a proper charge against the employing municipality.

For further details contact the State Dept. of Health or the Municipal Training Inst. promptly—Att'n. Morgan Strong, Director, 6 Elk St., Albany, N.Y.

Practical Aspects of Sewage And Waste Chlorination*

by L. F. WARRICK**, *Stream Pollution Control Division, U. S. Public Health Service, Washington, D.C.*

THE practical aspects of chlorination of sewage and wastes are to be considered herein primarily from an operational point of view. The intent is to give as concise a presentation as possible of practices that have been developing in recent years, and that have an important bearing on stream sanitation. Present knowledge of the application of chlorine and its compounds in treatment of sewage and industrial wastes represents an evolution from simple to more completely developed procedures, constituting modern methods. While much has been accomplished in the past in this field, there remains much to be done before we can realize the full benefits to be expected from chlorination in stream sanitation.

The primary role assigned chlorination is sewage disinfection. As regards the public health aspect of stream sanitation, chlorine plays a distinguished role. Odor control, grease removal, better sewage clarification, reductions in oxygen demand, control of filter flies and ponding difficulties, and various other benefits from chlorination, however, will be of special appeal to the treatment plant superintendent and operator. There is considerable experience that has been covered in the literature to show the important aids chlorine furnishes with various plant processes. Such aids will be briefly discussed as they often have a definite bearing on overall functioning of the treatment works and results obtained in controlling pollution.

Sewage Disinfection

Early Development

The first use of chlorine for disinfection of sewage was at Hamburg, Germany, in 1893. About a year later the initial use of chlorine for this purpose occurred in the United States at Brewster, N. Y., where sodium hypochlorite was used by A. E. Woolf to protect the Croton water supply for the City of New York. About the beginning of the century Rideal[1] conducted important studies in England on the subject, as did also the Royal Testing Institute in Germany.

Investigations by Phelps and Carpenter in 1906 and 1907 at the Massachusetts Institute of Technology [2], and by Phelps and Daniels at Redbank, N. J., [3] a little later constituted the real start of sound sewage chlorination practice in the United States. Following the introduction of liquid chlorine to sewage treatment in 1914 at Milwaukee, Wis., and Altoona, Pa., use developed rapidly at other plants. At the present more plants in the United States use chlorine for disinfection than elsewhere throughout the world. Most of the 1,320 plants listed

Sewage Chlorination Equipment at Buffalo, N. Y.

*This paper was one of two on "Sewage Chlorination" presented as part of the 2nd Inservice Training Course of the School of Public Health, Univ. of Michigan. The companion paper, "Fundamentals of Sewage and Wastes Chlorination," by Prof. E. W. Moore of Harvard Univ., was published in *Water & Sewage Works* for March, 1951.

**Mr. Warrick is now Chief, Tech. Services Branch, Div. of Water Pollution Control, U.S. Public Health Service, Washington, D.C.

as having chlorination in a 1946 survey [4] had provided such treatment for sewage disinfection.

From the stream sanitation point of view the purpose of chlorination of sewage is to minimize contamination by bacteria and viruses of the streams or other bodies of water used for public water supply, shell-fish propagation, and recreational purposes, such as for swimming. Effective disinfection requires that there be a slight chlorine residual after a suitable contact period.

Chlorine Residuals

When primary treatment alone is provided for the sewage, pre-chlorination ahead of the settling tank or clarifier can usually best be employed to secure the proper detention time for disinfection. Chlorine contact tanks may be utilized, or application may, in some cases, be made just ahead of a long outfall sewer that will permit adequate contact period before the effluent reaches the point of discharge. Should secondary treatment be used at a sewage plant, suitable detention can be secured by adding chlorine ahead of the final clarifier, a contact chamber, or a long outfall sewer.

Generally the residuals to be maintained after contact in plant units will need to conform to health department regulations. The operator should familiarize himself with the requirements for his state, as there are variations in the amounts of the residuals and the contact time specified. The average requirement would probably be, for sewage disinfection, about 0.5 ppm. after a 15 minute contact period.

With some types of receiving bodies of water the method of establishing fixed chlorine residuals may not be accurate enough to assure attainment continuously of the desired degree of disinfection. A number of investigators [3, 6, 7] have indicated that dependence should not be placed upon such a chlorine residual as indicated above, as it does not offer a reliable index of the expected density of coliform bacteria.

Standards of disinfection to assure a suitable degree of cleanliness in waters receiving sewage effluents have been increasingly established, particularly with the increasing public pressure for cleaner waters. For example, the Interstate Sanitation Commission of the states of Connecticut, New York and New Jersey has set a standard under their compact, specifying as follows: "All sewage discharged or permitted to flow into Class A waters of the district shall first have been so treated as . . . . . to effect a reduction of organisms of the B. Coli group (intestinal bacilli) so that the probable number of such organisms shall not exceed one per cubic centimeter in more than fifty per cent (50%) of the samples of sewage effluent by the partially confirmed test; . . . . ." [3, 9]. This standard requires, in other words, a coliform index having an M.P.N. of 100 per 100 ml. The sewage plant operator is confronted with the problem of adjusting chlorine dosage to attain a high degree of stream sanitation.

Eliassen [10] attempted to arrive at some answers to questions raised through a statistical approach to sewage chlorination. From studies conducted it was concluded: ". . . . . 4. Actual chlorine dosage maintained at a fixed value in parts per million is not a reliable method of control of the chlorination process in any sewage treatment plant. 5. The rational method of chlorination control is to maintain a fixed value of chlorine residual in the sewage after a specified contact period in order to attain a stipulated coliform index in the effluent 50 per cent of the time. 6. The chlorine residual necessary to achieve the stipulated coliform index may be predicted for any sewage treatment plant by the performance of four series of ten chlorination experiments, and statistical evaluation of the results of these experiments."

Chlorine Dosages

Meeting a certain chlorine residual requirement at the end of a given contact period is merely assuring satisfaction of the chlorine demand of the sewage. The principle consideration, therefore, is the chlorine demand of the sewage or effluent to be disinfected. It has been found by wide experience that the chlorine dosage needed for disinfection of raw sewage usually varies from 10 to 20 ppm., but with strongly septic raw sewages it may take as high as 40 ppm. With secondary treatment effluents, the dosages range from 6 to 12 ppm.; for trickling filters, from 3 to 6 ppm.; for sand filters, from 2 to 4 ppm., for activated sludge plant effluents.

The presence of industrial wastes often exerts a material effect on the chlorine requirements for disinfection. From studies at Buffalo, N.Y., Symons, Terhoeven, and Torrey [11] determined that chlorine required for effective disinfection of raw domestic sewage was 0.005 lbs. of chlorine per capita per day. In Buffalo, industrial wastes brought up the chlorine requirements to 0.01 lb. per capita per day. Each community's sewage and waste will offer its own problem of determining a chlorine dosage that will assure adequate disinfection.

Regulation of Dosage

In most cases manual control of chlorination is practiced. Operators periodically check the chlorine resi-

Automatic Chlorination Control Equipment at Ft. Wayne, Ind.

duals by orthotolidine or the thiosulphate starch-iodide methods, making suitable adjustments in the rate of feed. Griffin and Campbell [18] point out that the variations in chlorine demand are quite marked during the hours of operation each day, with no correlation between volumes of flow and chlorine required to produce a residual. In situations cited, the chlorine required increased 8 to 10 fold when the flow doubled. Automatic control based on volume, therefore, leaves much to be desired in sewage disinfection. Two relatively new methods of chlorination, "step by step" chlorination and "potential chlorination" were advocated as more efficiently and economically meeting chlorine dosage control requirements. The first method is based upon preselection of the rates of feed for hourly intervals based on past experience, and the second depends on the use of an electrode system which actuates an automatic recorder which in turn regulates the chlorinator. In large plants, where economy in use of chlorine is an item, automatic accurate control is very desirable.

The frequency of performance of residual chlorine tests determines in large measure the results to be secured or protection afforded the receiving watercourse. At the largest plants where the personnel is adequate and laboratories available this is no problem. At Los Angeles and Buffalo the regular operating procedure is to keep close checks on chlorine dosages by taking hourly chlorine demand tests.

Odor Control

Chlorine was used for odor control before it was used for sewage disinfection. The earliest recorded practice of chlorination appears to be the use of chloride of lime by the Royal Sewage Commission of Great Britain in 1854 to deodorize sewage of London. In the United States in 1912 use of chlorinated lime was tried by Ellms and Waring for odor control with a septic tank in Cincinnati. Chlorination of sewage in an outfall sewer was tried early at Cleveland to control odors. Because of odors encountered with Imhoff tanks, use of chlorine for preventing nuisances spread rapidly with the installation of these tanks. Odor control is one of the major problems that operators have had to contend with over the years.

Odors are present, to some degree, part of the time at least at most plants. They vary in intensity or intrusiveness, and with plants too near built-up areas, complaints may be expected unless every precaution is taken to control obnoxious odors. There have been numerous lawsuits caused by odors in the past, and these may prove costly.

The objective in odor control is to prevent odors developing or sufficiently reduce those that already exist to avoid complaints. Numerous compounds present in sewage, such as indole and skatole, produce odors at sewage plants. Hydrogen sulfide is the worst offender. Heukelekian[19] has shown the chlorine application necessary for effective odor control is intimately associated with the chlorine demand and the degree of hydrogen sulfide production. A minimum of 20 to 25 per cent of the chlorine demand needs to be satisfied to keep the sulfide content in sewage settling basins below 1.0 ppm., and in some cases as high as 50 per cent of the chlorine demand must be satisfied. In practice the chlorine dosage has varied from 3 to 15 ppm., instead of the theoretical 2.22 ppm., for removal of each ppm., of sulfide; due undoubtedly to demand for chlorine exerted by other substances present in the sewage. The odors arriving with the sewage at the plants are often produced by slimes on the submerged surfaces of the sewers. This may suggest as a remedy that for most effective results chlorination be applied at a remote pumping station, in a trunk sewer or interceptor.

Odor control does not have a direct bearing on stream sanitation. Odors, however, create operating problems which may indirectly affect the otherwise efficient functioning of a treatment works. No further discussion will be given this matter as there is considerable information in the literature on chlorination for odor control.

B.O.D. Reduction

When chlorine is employed for various purposes in sewer systems a beneficial effect in reduction of the B.O.D. of the sewage is experienced. Where prechlorination has been used for reducing plant overloads, each ppm. of chlorine will reduce the B.O.D. approximately 2 ppm.,[19]. The rate of reduction appears to be fairly constant until the chlorine residuals are obtained, as essential with sewage disinfection. In producing a residual, sufficient chlorine has generally been added to the sewage to reduce the B.O.D. load in the plant from 15 to 35 per cent. The decrease is most significant with strong sewages, very septic sewages, sewages containing industrial wastes, and in situations where supernatant is being returned ahead of the plant. It is not economical to add chlorine in amounts beyond that necessary to obtain a chlorine residual. Beyond that dosage the amounts of chlorine added give less reduction, and such additions have been considered unwarranted for control of plant overloading. This is brought out by Griffin and Chamberlin[18] while exploring the effect of heavy doses of chlorine in sewages.

Haseltine[20] has described how changing from post chlorination to prechlorination ahead of primary clarifiers at a sewage plant like Butler, Pa., brought about greater B.O.D. reduction through one clarifier than was previously obtained with series operation of two clarifiers.

Rawn[21] has reported an outstanding instance of B.O.D. reduction in which chlorine was applied to the highly septic raw sewage which was reaching an activated sludge plant. It was reported in this instance that the capacity of the plant was trebled.

Aids to Clarification

The basic functions of a sewage treatment plant are to reduce the solids, B.O.D. and bacterial loadings delivered to receiving streams. It has been observed that one of the benefits of prechlorination for various purposes discussed has been decided improvement in clarification of primary tank effluents. Cohn[22] reported this effect over twenty years ago. A few of the communities indicating improved settling rates and less suspended matter in tank effluents were Annapolis, Md., Clearwater, Fla., Kankakee, Ill., Lufkin, Texas, and Racine, Wis.

The chlorine acts to (a) improve the settling rate of sewage, (b) control septicity of raw sewage, (c) increase grease removal, and (d) assist in chemical precipitation processes, all of which improve clarification. As little as 1 ppm., of chlorine will increase the settling rate of fresh sewage while septic sewage requires a minimum of about 2 ppm., for some improvement.

Chlorination is a most useful adjunct to primary treatment plants to take care of seasonal conditions of low flow, or of use of waters during summer months for recreational bathing.

The usual practice is to reduce the loads on streams during critical periods by prechlorination before settling, with attendant B.O.D. reductions through the tanks or clarifiers. Post-chlorination is also employed with success, with removals of B.O.D. being reported up to 50 per cent, the usual reduction being 25 to 35 per cent.

In general, chlorination sufficient to give a residual at the point of discharge is advisable. According to the report of the A.P.H.A. Committee on

Sewage Disposal,[30] chlorination sufficient to produce a chlorine residual in the stream receiving the chlorinated sewage or effluent will retard the normal decomposition processes and will tend to prevent anaerobic conditions during the normally critical periods of rapid oxygen depletion. An opportunity is afforded for reaeration and additional dilution to take place from springs and tributary streams to maintain aerobic conditions. However such chlorine loses its effect rapidly in water courses having large sludge deposits.

Hedgepeth[30], in discussing trade wastes, indicated that sanitary engineers usually did not think of chlorine as a pollutional substance, but that it would need to be so classed if "too much" was discharged into streams containing game fish. As little as 0.3 ppm., of chlorine in the stream water may prove deleterious to some fish.

Control of Bulking Sludge

Difficulties with sludge bulking in activated sludge plants, with resulting deterioration of effluents discharged to streams, may be overcome by chlorination in some cases. Much is yet to be learned regarding bulking. Such effects are known to result from the presence of certain trade wastes. Fungus growths have been indicated as a factor. The role of chlorine in activated sludge bulking control has been explained in various ways. Where fungus growths are involved, chlorine has been found effective in destroying or suppressing these growths. Undoubtedly part of the biological life is killed in the return sludge. This has probably been described best by Tapleshay in his statement that the chlorine restores the balanced load between the organic matter and the biological life present in the sludge. The procedure he outlined to best take care of such problems in plant operation is essentially as follows:

(1) Apply chlorine to the return sludge at least two minutes ahead of where it mixes with the primary effluent; (2) use chlorine in an amount computed from the Tapleshay formula; (3) keep the rate of return sludge as near a constant percentage of the flow as possible during chlorination; and (4) seldom adjust the chlorine dosage day by day. The reason for the latter is that as the sludge index decreases the concentration of the return sludge increases as it becomes more compact. Chlorination is continued until the sludge index returns to the normal value for the individual sewage treatment.

Usually a decided improvement is noted in 3 or 4 days. Chlorination for sludge bulking is usually discontinued in 7 to 10 days. The amount of chlorine required to control sludge bulking increases with the suspended solids concentration and with the sludge index. The chart developed by Tapleshay covers a wide range of values for these two figures, which make use of anywhere from 2 to 24 lbs. of chlorine per 100,000 gal. of returned sludge. Under normal conditions, the amount of chlorine required will vary between 2 and 8 ppm., averaging 5 ppm., based upon the flow of returned sludge.

Inferior quality effluents from activated sludge plants may be due to abnormally large concentrations of grease in the raw sewage. Even though a large amount of grease is generally removed with the settleable solids in primary treatment, it has been found in some plants that prechlorination in conjunction with preaeration results in considerably improved removals of grease in the primary units. When the amount of grease reaching the aeration tanks of the activated sludge system is decreased, a lower grease content in the sludge results. A return sludge having greater oxidizing ability is produced.

Other aids to the operation of activated sludge plants that may be accomplished by chlorination include such items as diffuser plate cleaning. This has become a serious problem at some plants. Experience has shown that relief can be secured by adding chlorine directly into the air header, one unit at a time. Common practice is to use intermittent applications of chlorine, at rates of about 3 or 4 lbs. per hour for about 2 to 3 hours per day. From 12 to 15 lbs. of chlorine, therefore, will be needed in maintaining continuous treatment to keep the plates in satisfactory operating condition.

Chlorine used in the above manner will not control clogging entirely, but with proper care it should make it unnecessary to remove plates at intervals of less than 2 years. The use of chlorine in prolonging the interval between removals and usual cleaning with acid or by burning appears to be well worth considering in activated sludge plant operation.

Other Sewage Treatment Aids

Several other aids provided by chlorination at sewage disposal works that should be mentioned include control of foaming, particularly of Imhoff tanks, supernatant and waste activated sludge conditioning, and application in sludge thickening. When chlorine is used for foaming control with Imhoff tanks, prechlorination of 3 to 15 ppm. is generally sufficient. Such treatment will often completely stop foaming troubles, or at least it has been helpful in many situations. Return of digester supernatant liquor to the influent to primary tanks has been offering difficulties, occasioned by the periodic overloads. An application of chlorine amounting to from 20 to 80 ppm. gal. of supernatant is reported to be quite beneficial in reducing these loads on the plant.

The mixture of the supernatant and raw sewage is chlorinated ahead of the primary tanks or clarifiers. By using a small continuous discharge of supernatant there may be necessary only a small increase in the rate of prechlorination. When waste activated sludge is concentrated or thickened it has been reported that chlorine has aided in avoiding bulking and in reducing the water content. To obtain effective results with the chlorine in sludge thickening, a chlorine residual needs to be maintained in the liquor above the settling sludge as it compacts in the tank. Those utilizing this procedure agree that a 1 ppm. residual needs to be maintained in the clear liquor over the sludge.

From the foregoing, it is apparent that chlorine is especially helpful in bettering operating results at overloaded plants. It has been employed in oxidizing, sterilizing, controlling odors, retarding decomposition, and coagulating protein substances. These properties warrant further study and utilization where possible in sewage and waste treatment, thereby furthering stream sanitation.

Industrial Wastes Chlorination

Some effects of chlorination of trade wastes that might be mentioned in relation to stream sanitation involve toxic effects to fish through chlorine products found with gas works or chemical plant wastes containing thiocyanates. Not enough data to establish the toxic limits was furnished but evidently the products are fatal to fish life in fairly substantial dilutions in a receiving stream.

Harlow[30] has brought out in a recent article that biological treatment of wastes containing certain chemical substances may prove difficult or impractical if chlorinated. He cites experiences with some chlorinated phenolic wastes that needed special treatment, due apparently to chlorine substitution in the para position creating compounds not susceptible to biological treatment.

Faber[30] has outlined a new treatment process for wool scouring wastes using a calcium hypochlorite solution.

It is stated that 98 per cent of the grease contained in the raw wastes is removed, and nearly 75 per cent is reclaimed for marketing. About all the suspended solids are removed along with 80 to 90 per cent of the B.O.D.

It has been indicated by Howard[23] that addition of 300 ppm., of chlorine effectively coagulated suspended solids in tannery wastes, and substantially overcame odor conditions in a stream. Marshall[22] calls attention to the marked increase in chlorine demands at a primary sewage treatment plant due to beet cannery wastes, such demands varying from 220 to 460 ppm., during the beet pack. The color of the wastes interferes with use of the orthotolidine method for determining residual chlorine. Disinfection of the sewage is seriously interrupted, the effluent having 100 E. Coli per ml. when the domestic sewage alone is treated, and up to 1.25 million per 100 ml. during the beet canning season.

Numerous applications for chlorination in trade waste treatment are already indicated by research and development work, as well as special problems of the type just reviewed where alterations in methods will be necessary to avoid harmful effects on streams.

Methods for the ready measurement of sub-O. T. residuals[20], for establishment of changes effected in organic substances in sewage and wastes, and for the performance of essential control tests at treatment works are steadily being developed. These tools for advancement of our knowledge need to be increasingly applied and still better procedures found to aid progress.

With new, improved methods of sewage treatment being developed, with the treatment of industrial wastes being studied, chlorine appears especially suited for processes that require oxidation, disinfection, control of odors, retarding of the decomposition of protein matter, and coagulation, alone or along with other chemicals, of substances causing pollution.

In conclusion, there is a steadily broadening horizon for chlorination in sewage and waste treatment. Though the progress made in the past has been quite substantial, and accomplishments quite real, it is stimulating to look forward to inevitable future progress with the many benefits that will accrue in betterment of stream sanitation.

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A. M. Rawn Appointed To National Pollution Control Board

Carl H. Chatters Also Named

President Truman has appointed two men to the National Water Pollution Control Advisory Board which functions in an advisory and recommending group to the President and the U.S. Public Health Service in all matters pertaining to stream pollution control at the Federal level.

One of the appointees is A. M. Rawn, Chief Engr. and Genl. Mgr., Los Angeles County Sanitation Districts, and long standing Editorial Associate of *Water & Sewage Works*.

The other appointee is Carl H. Chatters, Exec. Director, American Municipal Ass'n, Chicago.

N. C. Section Staging Another Meter Repair School

Because of popular demand the School for Meter Repairs, sponsored by the North Carolina Section of A.W.W.A., is being repeated this year under the direction of J. L. Greenlee, Asst. Supt., Charlotte, N.C., Water Department. As in the case of the earlier successful schools this one will be held in the shops of the Charlotte Water Dept.

Demonstrations of step-by-step testing—and repairing—and renovation of meters of various sizes and makes will be made by Charlotte Water Dept. employees, representatives of several meter manufacturers. In addition, demonstrations of the uses and value of the recording "Meter-Master" (otherwise known as the "Water Works G. Man") will be made by Stanford Harris, Supt., at Winston Salem, N.C. "Requirements and cost of Establishing a Meter Repair Shop and Program for the Smaller Cities" will be set forth by Richard Ford of Ford Meter Box Co.

The N.C. Meter Repair School will be held April 13th and 14th, with Hotel Mecklenburg, Charlotte, N.C., as the point of registration.

[Ed. Note: We regret the fact that this announcement prepared from the School Program just received will be rather short notice in our April issue. However, we are printing it with the thought that the idea of Meter Repair & Maintenance Schools is something which should be duplicated in other sections.]

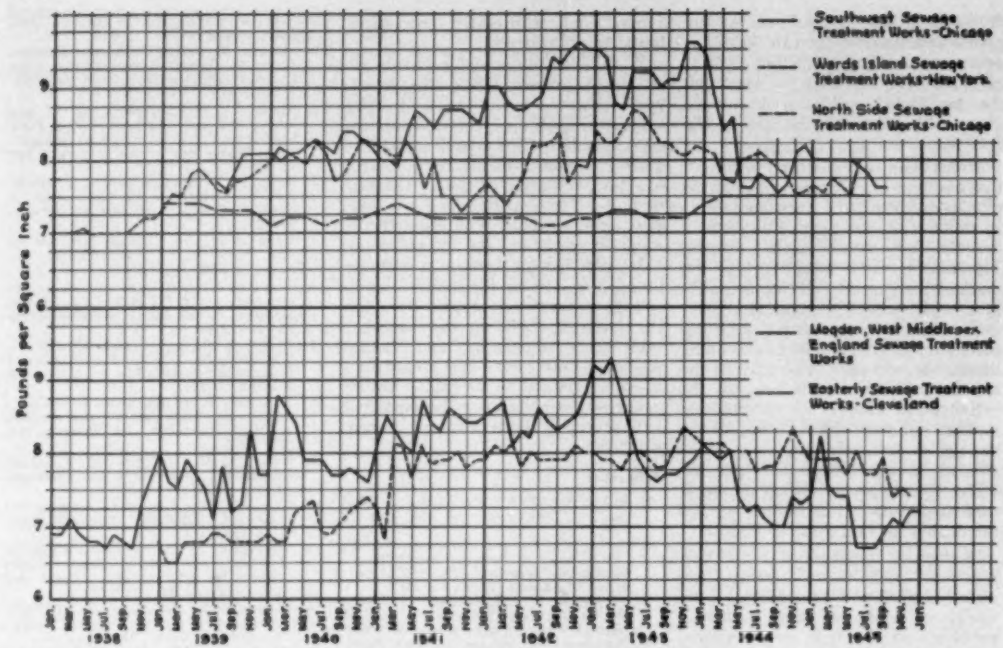


Fig. 1—Pressure of Air Supply to Aeration Tanks at Five Plants

Air Diffuser Maintenance

by FRANK C. ROE, *Development Engineer, The Carborundum Company, Perth Amboy, New Jersey.*

EVER since the successful development of the activated sludge process in 1914, followed by several other aeration processes or beneficial applications of air for sewage treatment (and some water treatment), there has been a constant effort to improve the methods or devices used for aeration. Such progress, of course, is a normal phenomenon when effective and, generally, economical processes have become established. This progress has been based on these equally normal objectives:

1. Desire for increased efficiency (of oxygenation),
2. Desire to reduce maintenance generally and thus minimize cost of aeration.

Pointed towards the first objective of increasing efficiency, many devices and/or methods of aeration have been tried; *some of them more than once*, and several of them patented. A great deal has been written on this subject involving, for example, the relative values of air diffusion and surface oxygenation from the atmosphere, but that comparison is beyond the scope of this outline. A thorough consideration of all ideas leads to two basic conclusions: (1) That diffusion of air bubbles has proved to be the most efficient method of aeration, and (2) that porous ceramic diffusers similar to the type originally found to be most efficient continue as the standard and most satisfactory device or material to accomplish the job.

The greatest increases in oxygenation efficiency have come about by improvement in aeration tank design and diffuser distribution. Specifically, the two major improvements have been: (1) The use of "spiral flow" tanks instead of "ridge and furrow" and (2) the spreading of diffusers to give a wider air bubble column in such spiral flow tanks.

The Maintenance Problem

The second objective of reducing diffuser maintenance is the prime subject of this outline. Basically, it involves keeping diffusers clean so that blower pressures and power cost will not increase unduly. An analysis of plants in service for ten or more years shows that many have required little diffuser servicing. The same survey indicates however, that maintenance of diffusers at a satisfactory level of efficiency frequently is a serious problem.

Figure 1 illustrates the magnitude of blower pressure increase when clogging develops and/or diffusers are not maintained in a clean condition. This was prepared by Superintendent J. J. Wirts of Cleveland's Easterly plant and provided cogent evidence to justify a diffuser servicing program. An analysis of each plant's experience would be too involved for this outline but the marked decrease in pressure loss from the maximum recorded at Cleveland (and elsewhere) indicates the eminent success of such a diffuser servicing program.

Diffuser clogging invariably is caused by one or more of the undesirable conditions that will be described in the following section. *Prevention of clogging usually is possible, as evidenced by the experience at many plants and should be practiced to the utmost within economic limits.* Prevention commences with the original *design* of the diffuser system. A favorable environment can then be maintained by means of good *installation* and *operation*. These three important prerequisites are described in the three sections that follow the outline of clogging sources.

Sources or Causes of Diffuser Clogging

Clogging is experienced on either or both the air and the liquid side of air diffusers.

The various well established causes, with a few being somewhat theoretical, are given below. Both types of clogging are listed in the approximate order of incidence. The order of listing has no significance as to degree or seriousness of clogging, however.

Air Side Sources

1. Dust, pollen or smoke particles in air supply.
2. Rust and/or other oxidized or foreign particles picked up in air supply system following filtration. Generally this is air piping scale, but there are other contributory sources as suggested.
3. Oil in air supply from filters or internally lubricated (reciprocating) compressors.
4. Sewage solids resulting from leaks into the air system when air supply is interrupted.
5. Condensation of moisture from air supply, especially during periods of high humidity. While this does not cause diffuser clogging in the true sense, the effect of increasing air pressure loss when water enters diffuser pores is the same. It is not noticeable with clean, new diffusers but may be 10 per cent or possibly more when clogging from some other source is existent. Tests in The Carborundum Co. laboratories on 20 grade plates clogged principally as per source 1. below, showed an 8 per cent pressure loss increase (at 4 cfm. per sq. ft.) with air ranging from 20 to 90 per cent relative humidity.

Liquid Side Sources

1. Finely divided inorganic solids (silt) and sludge solids which enter the porous diffuser structure when air supply is interrupted.
2. Precipitated coating; principally iron salts from industrial wastes and carbonates where water supply is hard.
3. Organic growth or fungi.
4. Grease.
5. Miscellaneous debris during periods when diffusers are exposed in empty tanks.

It is apparent upon reviewing this double list that an astronomical number of different combinations of causes of clogging is possible. Some combination is decidedly the normal case in practice. It is no more likely that two installations of air diffusers will have identical operating conditions with the same combined possible sources of clogging than it is that any two analyses of sewage and industrial waste will be similar. Consequently it is evident that each plant must develop its own best schedule and method of diffuser maintenance and cleaning, if it becomes necessary.

Diffuser Design and Specification

Recognition of the maintenance problem and efforts to minimize it have resulted in two basic advances in diffuser design: (1) The use of stationary plate or tube holders that permit simple removal of diffusers following tank dewatering and (2) the use of completely removable diffuser units (usually tube assemblies of which Fig. 2 illustrates the first example) without tank dewatering. Selection of either design is based on overall economic factors, which often favor completely removable diffusers because servicing can be accomplished on a unit progression basis during operation thereby avoiding standby aeration capacity, over-loading or by-passing.

A more important advance has been in the selection of higher permeability (grade) diffusers, with correspondingly larger pore size. It was presumed originally that small pore diffusers were essential to the release of minimum size air bubbles; hence maximum efficiency of oxygenation therefrom. Periodic work by A. J. Beck of The Sanitary District of Chicago throughout the past twenty years has established that there is little increase in bubble size between grade 20 and grade 80 diffuser plates. This is due to the fact that in a body of sewage etc. having a relatively low horizontal velocity component, bubbles must attain a diameter of approximately 0.1 in. before buoyancy overcomes surface tension and they are released.* The negligible difference in bubble size, as established by photographs, is sustained by the fact that dissolved oxygen in tanks aerated by small pore diffusers is the same as in tanks aerated by coarser grades.

The above phenomenon is fortunate because the prime justification of large pore diffusers is the critical fact that they are not so effective in intercepting minute foreign particles from the air supply as small pore diffusers; hence, they are not as susceptible to clogging on the air side. Of some added economic importance is that initial pressure loss through the larger pore diffusers is lower and that they probably respond better to cleaning methods.

Figure 3 provides a close approximation of the relation between average pore size of diffusers and grade of standard ceramically bonded aluminum oxide diffusers manufactured by The Carmorundum Co. Since the grade is based on permeability of 1 in. thick material (the standard for plates), it is apparent that thinner wall standard tubes will have a higher permeability for the same grade and pore size. Because of this fact it is recommended that all diffusers be specified on the basis of "grade" in order to obtain the desired pore size.

Grade 40 diffusers generally are recommended where air supply can be maintained in a clean condititon. Grade 60 or grade 80 are suitable where air cannot be filtered satisfactorily but good initial air distribution may be more difficult with these low pressure loss units. Orifice control can be added to assure uniformity although equalization of pressure loss throughout a system normally is obtainable with branch air line valves.

To a considerable extent, the foregoing DESIGN requirements, in addition to those listed under INSTALLATION and OPERATION to follow, are premised on the discussion of each subject in the Air Diffusion Manual to be published by the Federation of Sewage and Industrial Wastes Associations. It is beyond the scope of this outline to give further specifications. They will be covered in greater detail in the Manual.

Diffuser Installation

To prevent as much clogging as possible from the sources as outlined, minimize maintenance expense and generally insure maximum efficiency of air diffusers, there are several somewhat obvious requirements of initial installation as follows:

1. The type of air filter equipment selected and its capacity must be such as to provide a supply that will not contain more than 1.0 mg. of foreign particles per 1000 cu. ft. under the worst anticipated atmospheric conditions. A concentration of 0.5 mg. per 1000 cu. ft. is the standard recommended for average conditions. Double air filtration frequently is necessary for this quality.
2. Air mains and branch air piping should be of such a material and so protected that there will be no scaling or other deterioration that will result in serious clogging of diffusers from the air side. For the same reason, all air lines must be thoroughly clean before operation commences.
3. The blower equipment selected must be of the type that will not contaminate the air supply with its lubricating oil or other foreign material.
4. All diffusers controlled by any given valve should have the same permeability rating within one (1) percent.† All diffusers on the same system should be installed level and to the same elevation within 0.05 ft. Those tributary to each

* A high liquid velocity across the surface of diffusers would tend to "wipe" air bubbles therefrom as they are formed. Under such conditions the small pore diffusers theoretically would provide more efficient oxygenation.

† Where orifice control is included with individual diffuser tube units this close control is unnecessary but it normally is possible on a given shipment of standard tested tubes.

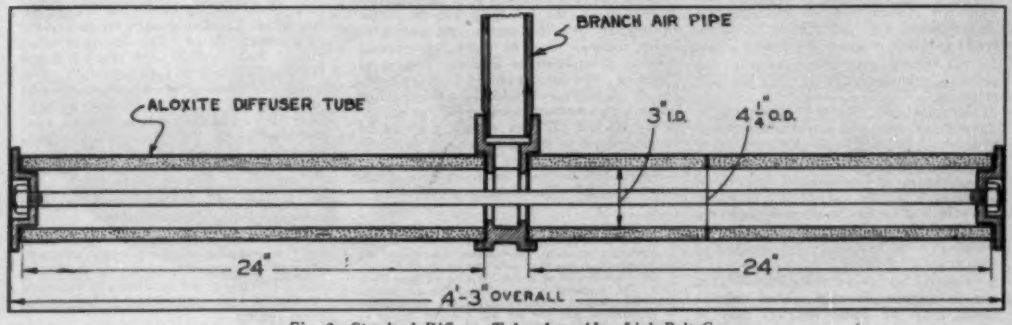


Fig. 2—Standard Diffuser Tube Assembly—Link-Belt Co.

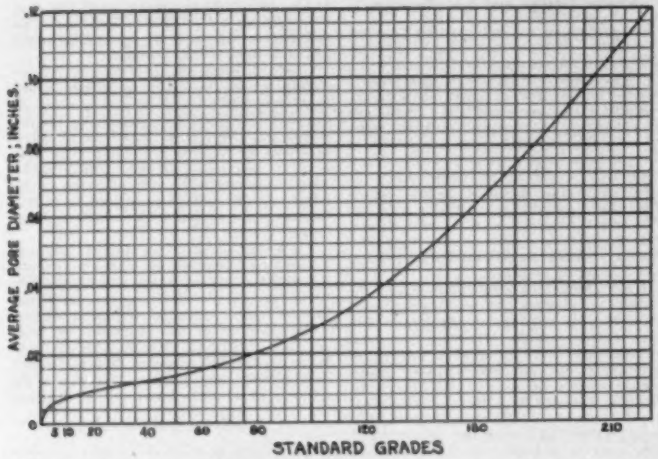


Fig. 3—Relation Between Average Pore Size and Grade of Alosite Porous Media

valve should be at the same elevation within 0.02 ft.

5. The entire aerator system should be initially tested for leaks with clean water above diffusers in order to prevent sludge solids from entering the air system during possible subsequent shutdowns. The system should then be protected until actual operation commences when the air must be discharging before liquor is introduced.

6. The general plant construction, source of blower power, aeration accessories etc. must be such that air supply shutdowns will be non-existent except as a result of unavoidable accident, catastrophic storm or similar occurrence.

Diffuser Operation

An aeration system must be operated in accordance with certain well established practices to keep maintenance cost and diffuser clogging at a minimum, thus requiring low blower pressure and producing generally high efficiency. The various factors involved as listed below are of perhaps even greater importance than those comprising the requirements for proper INSTALLATION.

1. A continuous air supply is the basic operating requirement for prevention of clogging of diffusers from the liquor side. In addition to installation requirement No. 6 described above, it is apparent that thorough blower and motor or engine maintenance, e.g., lubrication, is absolutely essential to avoid shutdowns.

2. Air filters must be constantly and properly maintained to prevent air side clogging.

3. Regular and thorough inspection of the diffuser system is essential to prompt location of leaks or non-uniformity, thus avoiding more serious difficulty.

4. Complete and continuous records of all aeration factors, e.g., blower pressure, likewise is essential to prompt discovery of any condition that ultimately may contribute to a decrease of diffuser permeability.

5. Control or prevention‖ of clogging due to organic growths within diffuser media near the liquid interface may be effected by periodic applications of chlorine gas with air supply.

Methods of Diffuser Servicing or Cleaning

While the theme of this outline of diffuser maintenance thus far has been prevention of clogging, the eventual necessity of permeability restoration through some degree of cleaning must be recognized as a strong possibility. If unavoidable conditions make the problem serious, a thorough analysis of the various known methods is justified. A regular schedule of servicing is then desirable, based on use of the most successful method that is economically justified and within the budget.

Two general procedures of cleaning have developed in keeping with diffuser design development: (1) for diffuser plates more or less permanently cemented into plate holders and (2) for diffuser plates or tubes that are easily removed from stationary or suspended type assemblies. These procedures can be broken down into methods used for liquid side clogging and those used for air side clogging. Rather than attempt a further classification based on methods used for different kinds of diffuser clogging, the established effectiveness of removing various kinds of clogging will be listed with each method.

Because of the practical certainty that any serious clogging is from a combination of sources, it is quite possible that a combination of cleaning methods will be required. For example, the left-hand Fig. 4 photomicrograph of a thin section cut from a 40 grade diffuser plate as taken from actual service, gives evidence of three sources of clogging. The areas marked *"A"* appear to be silt particles embedded in a precipitated coating that contains some iron. The darker areas marked "B" are chiefly the natural ceramic bond of the plate but the extended rough edges plus other minute dark spots indicate dust or some oxide particles from the air supply. The contrast with the right hand photomicrograph of a clean new plate of the same grade is quite apparent.

‖ An hypothesis for control or prevention of clogging due to progressive dehydration of solids or precipitation of salts, carbonates, etc. near the liquid interface has been proposed by R. C. French of the Department of Public Works of New York City. The proposal is to maintain the air supply near the point of moisture saturation. In addition to supposition that wet air will prevent drying of solids is the suggestion that it will neutralize minute charges that could otherwise develop a minor electroplating action.

A. Cleaning Plates in Place—Liquid Side

1. ACID TREATMENT has been used the most widely with different acids of variable strength and a variety of techniques or modifications. A concentrated solution containing 80 per cent sulphuric, 2 per cent sodium dichromate and 18 per cent water appears to be the most effective on serious clogging. Lower strength solutions, and also hydrochloric and nitric acids, should be tried because of cost factor.

The general technique is as follows: Clean plates by water hosing with air on; apply acid to center of each plate using approximately 150 ml. per plate; spread over surface with squeegee; allow to stand for a day or two; blow out with air. More or less acid may be applied depending on plate condition or the operation may be repeated before drying.

Variations of this technique and solution will be found effective for each situation and type of clogging. The method has been used for removal of organic solids, various precipitated coatings and growths from the top of plates.

2. CAUSTIC TREATMENT has been used infrequently with indifferent results but conditions may warrant trial. One method used is to clean plates as described above and leave plates with a small amount of water on the surface: Dissolve 0.1 lb lye crystals over each plate; shut off air; allow solution to penetrate 10 to 15 minutes; add water; blow out with air.

This method is reported as most effective for removal of organic compounds, grease etc. from plate surface.

3. AMMONIA TREATMENT has not been used frequently but is reported favorably. The method follows: Clean surface of plates by water hosing; include wire brushing if necessary; shut off air leaving plates wet; apply approximately 1 pint of a solution of 50 per cent household ammonia and 50% water to each plate; allow to stand overnight; blow out with air.

Method is applicable primarily to plates clogged with organic growths.

4. DETERGENT—WATER JET TREATMENT is the most recent successful method discovered and involved a combined operation. The detergent solution may be ½ pint of commercial liquid known as Glim mixed with 5 gal. of water and 1 qt. of ammonia. Another commercial liquid known as Nacconol is equally effective. The jetting which follows is considered to be an expulsion action within the saturated plate similar to water hammer.

Plates are washed first in usual manner and thoroughly blown out. About ½ pint alcohol is then poured on each plate as a wetting agent. The detergent solution is then applied until plate is saturated and allowed to soak overnight. The water jet cleaning which follows should be as violent and concentrated as possible. It can be accomplished with a 1 in. fire hose line at full pressure with nozzle reduced to ⅛ in. The jet is applied for about 30 seconds to each plate with the air off and then another 30 seconds with the air on, in order to locate spots that were missed by initial jetting.

While extensive experience is lacking on this method it undoubtedly removes all types of organic clogging on the liquid side. Inorganic solids also are loosened so that a high percentage is forced out upon jetting.

This method also should be applicable to the cleaning of suspended diffuser tube

assemblies in place although there is no report to date of such use. A special "ring" device has been developed by Chicago Pump Co. for uniform circumferential application of water jets. It simply is inserted over the end of each tube and moved manually from end to end.

5. Chlorine Purging has been used in relatively few places but with some good results. It is undoubtedly the most simple method known except drying.

With no preparatory step chlorine is taken from cylinders and introduced into the air main at a convenient location; preferably near aeration tanks. The rate of application will vary to meet conditions but a starting point and estimate of requirement is 2 lb. per 100,000 cu. ft. of air delivered. The operation is continued until blower operating pressure is reduced and/or until an adequate supply of air can be delivered to diffusers. This may take from two or three days to as many weeks.

Chlorine treatment is effective in removal of organic solids and growths from the diffuser surface. There is an indication of some help in reducing air side clogging from unknown sources simply as a result of the continuous purging action.

6. Sand Blasting is effective and reasonably fast on silica type porous diffuser plates but slower, and therefore costlier, on aluminum oxide type plates. Blasting should be done during air discharge to avoid further clogging by removed particles and sand. It is estimated that 1 minute is required per plate to remove ⅛ in. from silica type plates or 1/32 in. from aluminum oxide type plates. Accumulated sand and disintegrated plate material must be thoroughly cleaned out of tank after operation.

It is self-evident that this method will remove all types of top clogging. The extent of the operation depends on the depth of solids penetration.

7. Oxyacetylene Flame Spalling is effective in cleaning the surface of aluminum oxide type plates and is more economical than sand blasting. The best apparatus provides a wide flame as illustrated in Fig. 5. This self-propelled apparatus was developed by Linde Air Products Co.

The cleaning procedure involves preliminary plate washing and then setting a portable track alongside of plate holder as shown. Air is left on and the flame applied with nozzle moving over plates at linear velocity of 3 ft. per min. This removes approximately 1/32 in. from the surface and if clogging is deeper, the operation is repeated. Disintegrated plate material must be thoroughly cleaned out of tank after spalling.

This method is applicable to all liquor side clogging. Since it is costlier than other methods (except sand blasting) it is most practical on severe combined clogging that is not effectively eliminated by other methods.

8. Blow Torch Spalling is effective in cleaning silica type plates but is tedious and costly with increasing labor rates.

The procedure is to wash plates by hosing and scrubbing; dry with air discharge; apply blow torch flame at semi tangent with air on and remove material to required depth. Clean tank thoroughly after spalling.

As in all other methods involving removal of a thin layer of the diffuser material, blow torch spalling is effective on all kinds of liquid side clogging.

9. Drying is the simplest method of all, involving no expense other than for the air supplied. After draining tank, air is blown through diffusers for two or more hours, finishing with an extra high flushing rate. This is effective only in removing light organic (sludge) solids from the surface of otherwise clean diffuser plates.

10. Steam Purging has been used rarely but is reported as effective. Low pressure steam is applied to the air line and simultaneously the surface of plates is brushed vigorously with a stiff brush. Organic clogging and grease are removed with this treatment.

Care should be taken with this method to bring diffusers up to steam temperature rather slowly and to avoid a cooling shock after completion. This precaution is to prevent thermal shock cracking of the ceramic bond of diffusers.

B. Cleaning Plates in Place—Air Side

1. Sand Blasting has been satisfactory on silica type plates but has not been reported for aluminum oxide type plates. It involves removal of one end plate from each plate holder opposite air inlet and passing a sand blast nozzle under the plates by means of a special "boat" carriage.

The procedure is to dry plates thoroughly; remove end plate; insert boat with nozzle pointed upward 30° from horizontal; pass back and forth 3 times and swing nozzle from side to side enroute; remove and blow out plate holder at high rate with air from blower; clean sand and disintegrated plate particles from tank.

This method is effective in reduction of all types of air side clogging listed.

2. Gasoline Purging has only been reported at one plant where it is effective in removing a sudden incidence of oily smoke that cannot be intercepted by the air filters. Aviation gasoline is introduced into the air line at a rate of about 2 gal. per mil. cu. ft. Precautions must be taken to avoid possibility of explosion.

This method should be applicable to removal of grease or oil from other sources.

C. Cleaning Removed Plates and Tubes—Clogging on Either or Both Sides

The above heading applies because all of the methods listed below are at least partially effective in removing both liquid and air side clogging and because the simultaneous effect on both sides can hardly be avoided. The particular benefits of each method will be listed as heretofore.

1. Acid and Flushing Treatment is perhaps the most widely used and generally successful method of all. While acid pickling *alone* is partially effective and also is used extensively, the water

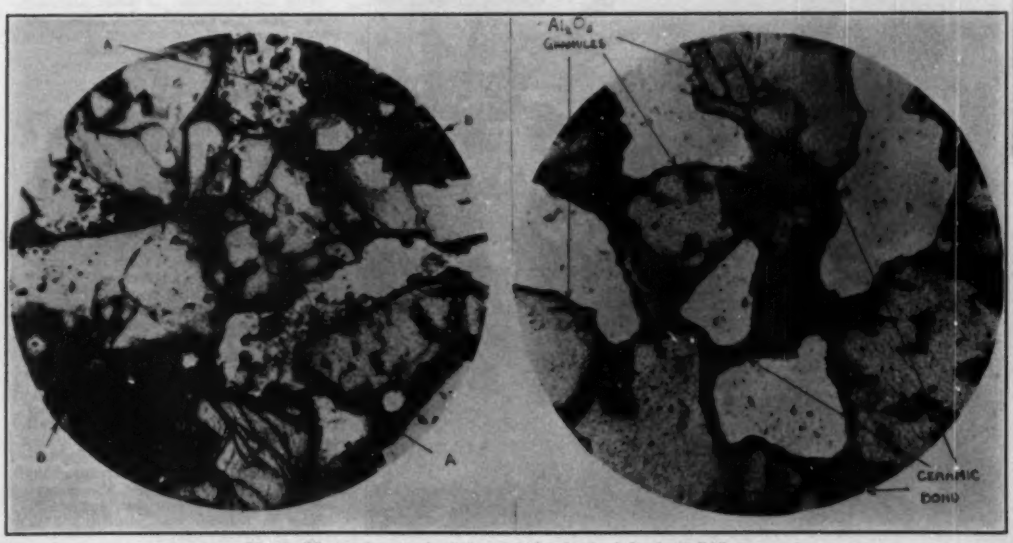


Fig. 4—Photo micrographs (x50 magnifications) of Grade 40 Diffusers
(Clogged Plate Structure) *(Clean, new, plate structure)*

and air flushing which follows adds much to the result. The second step has been well worth the extra equipment investment in the larger plants where used.

The initial step is to wash diffusers by hosing down in aeration tank; then blow out and dry with air discharge before removal from plate holders or tube assemblies. Submergence in concentrated sulphuric acid (2 per cent sodium dichromate may be added) is the next step, using a large stoneware crock. Diffusers then are placed in a large rubber lined steel soaking tank, similar to Fig. 6 and allowed to soak for as much as 48 hours. This tank is equipped with a drain for removal of spent acid and rinsing water which follows.

Flushing or scrubbing the treated diffusers with water and air is accomplished by clamping in a device similar to that developed at Cleveland's Easterly plant, Fig. 7. (Water and air inlets are connected to the box below plates and are controlled by quick opening valves. Drains are connected to the trough around the outside and a cover provided to prevent initial acid and water spraying.) The flushing time is determined by the operator based on uniformity of air bubble discharge.

This method is most successful in removal of organic solids and precipitates from the liquor side of diffusers. In addition, the flushing action undoubtedly removes some of the loosened undissolved inorganic solids from both sides. The reported diffuser permeability recovery at Cleveland and Chicago (SW) by this method, is from 80 to 90 per cent.

2. Reburning is unquestionably the most thorough method of cleaning known inasmuch as 100 per cent revivification is accomplished. If suitable kilns or furnaces are available, work can be done locally to save transportation. A more complete and satisfactory job probably can be done by the diffuser manufacturer with the type of kiln used for original vitrification.

Diffusers should be washed and dried before shipment for reburning. For ceramically bonded aluminum oxide diffusers, the process is to bring up to the maximum temperature slowly (about 50° C. per hour) and then cool at the same rate. The maximum temperature required for complete permeability restoration will vary with the kind of clogging elements present. Most materials burn out at low temperatures but silt normally is present containing small amounts of Si, Ca, etc. To fuse such elements into the structure and leave open pores, duplication of the maximum original vitrification temperature of approximately 1350° C., is desirable.

It is apparent that this is the most expensive method of cleaning, but it has these advantages: (1) recovery of diffusers equal to new diffusers, regardless of type of clogging; (2) accurately retested (for permeability) diffusers that will insure good initial uniformity of air diffusion upon reinstallation.

3. Caustic Treatment is used infrequently because of limited attack on clogging materials. In some cases, it supplements other methods to advantage.

The treatment consists of placing washed diffusers in a suitable iron vessel and boiling for several hours in a 10 to 15 per cent solution of sodium hydroxide. The time may be from 3 to 8 hours depending on conditions. Boiling in water should follow short treatment to dissolve soap.

Caustic treatment is effective in reducing the clogging from grease and other organic solids. It frequently must be followed by acid treatment to show marked results due to presence of other clogging elements.

Repeated hot caustic treatment over a period of several years should be done with caution because the silica content of the bond is slightly soluble therein. The structure accordingly would be weakened.

4. Detergent—Water Jet Treatment has the principal steps as outlined for cleaning plates in place and can be followed for cleaning of removed plates or tubes. For removed tubes, the Chicago Pump Co. has developed a device for water jetting following detergent soaking. Essentially, it is a ring jet enclosed in a vertical cylinder into which tubes to be cleaned are moved slowly in and out. An additional jet is provided for the inside if necessary. This device was developed primarily for cleaning of "Precision" Saran cord diffuser tubes manufactured by Chicago Pump Co. Tests indicate that it is likewise effective on ceramically bonded aluminum-oxide tubes, often supplied with Swing Diffusers by Chicago Pump Co. where conditions require.

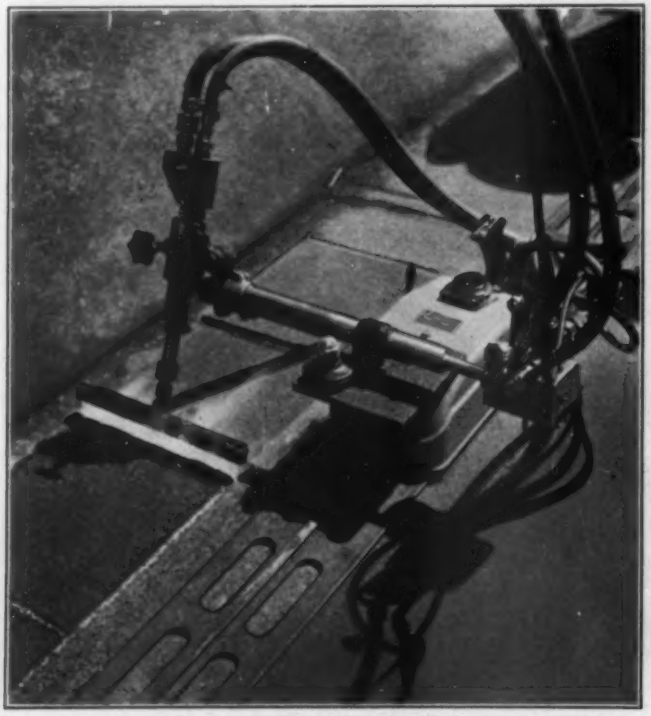


Fig. 5—Oxyacetylene Wide Flame Spalling Equipment (Linde Air Products Co.)

Economics of Diffuser Maintenance

As stated in the introductory analysis and review of the maintenance problem, the entire basis of its consideration must be that of cost. The elements of plant operation cost are so inter-related, especially within the diffuser system or "heart", that the economics of maintenance are extremely complicated.

It is apparent that diffuser economics is a special and extensive subject in itself. This concluding section, therefore, will merely outline the factors closely related to diffuser cleaning.

With the exception of large activated sludge plants, it is doubtful that many plants keep a separate accurate accounting on: increase of power cost, diffuser maintenance, and replacement sinking fund, for the diffuser system. Such records are critical, however, in establishing a clear picture of this subject. They will enable management to know how far it is possible to go in each direction in order to preserve an economic balance and to establish a realistic budget.

Cost of cleaning by the various methods reported vary extremely because of the variable degree of treatment required in each case, as well as the variation in cleaning method, plant size, labor required and other local factors. It is impossible, therefore, to put a price tag on each method as listed in the foregoing section. Under 1950 conditions, the cost of cleaning would appear to vary from a minimum of perhaps $0.10 per unit for the most simple methods (except drying), up to about $1.75 per unit for reburning.

A somewhat forgotten, yet quite important, factor in this problem of maintenance, is that of diffuser permeability. In the first place, diffusers do not clog uniformly from inlet to outlet of tanks. The permeability, therefore, will decrease and the pressure loss will increase by variable amounts, resulting in non-uniform aeration and decrease in over-all efficiency.

When it comes to cleaning, it is obvious that all diffuser units will not respond

Fig. 6—Soaking and Draining Tank for Acid Treatment

Fig. 7—Diffuser Plate Flushing Equipment

(Both at Cleveland Easterly Plant)

uniformly to treatment so that considerable variation from original permeability ratings will result. Without retesting and subsequent reinstallation in accordance with specification No. 3 under INSTALLATION, a tank equipped with cleaned diffuser units would resume operation with some non-uniformity. There is an automatic tendency towards correction of initial non-uniformity, but it is believed that equalization takes place at a slightly higher pressure than may be necessary.

Most of the large activated sludge plants are equipped with diffuser permeability test apparatus. Where smaller plants find it essential to adopt regular cleaning, the installation of simple testing equipment will be found profitable.

Summarizing this phase of the subject, one can only return to the original theme, expressed by one word: *prevention*. Observation and practice of the factors of prevention as outlined herein will pay large dividends.

Acknowledgment

The data and information compiled in this outline are the result of several years' accumulated notes based on reports, personal contacts and correspondence with many sewage works engineers who have a vital interest in the subject. The author wishes to express appreciation to all who have cooperated so kindly. It is desired to acknowledge assistance from the Tentative Manual on Air Diffusion as produced by the entire committee of the Federation and from the following persons in particular:

N. E. Anderson, Chairman, Sub-Committee on Air Diffusion, F.S. & I.W.A.

A. J. Beck, Member, Sub-Committee on Air Diffusion, F.S. & I.W.A.

G. P. Edwards, Member, Sub-Committee on Air Diffusion, F.S. & I.W.A.

J. J. Wirts, Supt., Easterly Sewage Tr. Works, Cleveland, O.

W. A. O'Leary, Chief, Sewage Disposal Design, New York City, D.P.W.

W. Torpey, Engineer, Sewage Plant Operation, New York City, D.P.W.

R. C. French, Engineer, Sewage Plant Operation, New York City, D.P.W.

Miles Lamb, Mgr., Eng. Dept., Chicago Pump Co., Chicago, Ill.

Technical Staff, H. C. Martin, Director, The Carborundum Co., Niagara Falls, N. Y.

Frank Lovejoy to Address Mfrs. Association at Miami

The annual business meeting of the Water and Sewage Works Manufacturers Association will be held on Wednesday, May 2, 1951 in Miami, Florida, at the Columbus Hotel, during the 1951 American Water Works Association Convention.

Featured speaker of the W.S.W.-M.A. luncheon on May 2 will be Frank Lovejoy, Marketing and Sales Executive of the Socony Vacuum Oil Company, Inc. Mr. Lovejoy is past President of the Sales Executives Club of New York and will draw on his wide experience in sales, marketing and his first-hand knowledge of the water works industry in addressing W.S.W.M.A. members and guests on sales problems confronting water works manufacturers today.

In making this announcement, Robt. F. Orth, President of W.S.W.-M.A. states that the meeting will begin with refreshments and entertainment at noon on May 2 in the Columbus Hotel's Peacock Promenade, followed by the luncheon and business session which will be staged in the adjoining Biscayne Room.

A Future W.W. Super?

"Just think, Dear—Some day he may grow up to be the Water Works Superintendent. Then we can sprinkle our lawn just as much as we want to."

Purdue Industrial Waste Conference

Sixth Meeting Highly Successful

ABOUT every 14 months since the fall of 1945, Purdue University has held a conference on Industrial Waste. Each year the sponsoring organizations, cooperating with Purdue, have included the Indiana Stream Pollution Control Board and Conservation Dept., the State Chamber of Commerce, the Indiana Manufacturers Assn., Dairy Products Assn., Canners Assn., and Brewers Assn., and the Indiana Section of the AWWA. This year an added sponsor in the cooperative effort was the Central States Sewage Works Assn.

Each year, too, the conference has been held under the direction of Purdue's School of Civil Engineering (Prof. R. B. Wiley, Head), the Technical Extension Div., and the Ind. State Board of Health. From the very beginning the conference set a high standard in caliber of papers presented and has drawn attendance from high technical levels of many industries, schools and governmental agencies. Originally intended for the benefit of industry in Indiana, the fame and importance of this meeting has grown to such an extent that the 390 registrants this year were drawn from 27 states and Canada. Much of the success of Purdue's Industrial Waste Conferences is due to Don E. Bloodgood, Prof. of Sanitary Engineering at Purdue, and chairman of the conference.

Chairman

D. E. Bloodgood
Prof., San. Engr.
Purdue Univ.
Lafayette,
Ind.

Programmers

R. B. Wiley
Head,
Civ. Engr. School
Purdue Univ.
Lafayette, Ind.

L. F. Warrick
Chief, T.S.B.
Div. Wat. Poll. Cont.
U.S.P.H.S.
Washington, D.C.

A. E. Gorman
San. Engr.
Div. of Engng.
Atom. Energy Comm.
Washington, D.C.

J. H. Murdoch, Jr.
Vice Pres.
Am. Wat. Wks.
Serv. Co.
Philadelphia, Pa.

Heavy Schedule

Beginning on Wednesday morning, Feb. 21, the meeting ran through until Friday afternoon at 5 p.m. In order to schedule all of the 54 technical papers presented, three or four simultaneous sessions were held each morning and afternoon, each paper starting on the hour. By adhering to this schedule it was possible for a person to hear 6 papers out of a possible 18 each day. In many instances the choice of concurrent topics was hard to make, because there was something of interest to all, and much of interest to many.

In addition to these technical papers on industrial waste, there was an evening banquet addressed by R. J. Kryter, Treasurer, Esterline-Angus Co., Indianapolis, Ind., who spoke dramatically and gravely on "Atomic Power in War and Peace." There was also a luncheon meeting which was addressed by B. L. Dodds, Dir., Div. of Educ. & Applied Psychology, Purdue Univ. Prof. Dodds gave a highly illuminating talk on the power of and necessity for public education. He pointed out that the development of America's present status through its application of power to free man from labor, had not only been possible through the use of education, but had made it necessary to provide education in order that its citizens could carry on the highly specialized work of today. It is public education, and the application of scientific knowledge which gives us courage in these troubled times to face, unafraid, a possible conflict with states or countries whose sole strength is uneducated manpower and slave labor under dictatorial governments.

The WPCAB

"The WPCAB in Pollution Control," by L. A. Danse, Supervisor of Production, Engineering Section, General Motors, Detroit, Mich.

Mr. Danse, who is a member of the Water Pollution Control Advisory Board, spoke extemporaneously on the work of that board. He outlined briefly its inception and organization, told how it had held meetings in various parts of the country and observed, first hand, various local situations. Mr. Danse expanded on the organization and work of the Technical Task Committees set up for various industries, and he reiterated the principle of cooperation of the State Health Departments with the Public Health Service. Mr. Danse also made it abundantly clear that industry, locally as well as nationally, must make a cooperative approach to the problems of pollution. Such efforts are essential in order that national defense efforts shall not be hindered by polluted water supplies.

USPHS Activities

"Activity and Accomplishments in the Various River Basins," by A. H. Wieters, Asst. Chief, Div. of Water Pollution Control, U.S. Pub. Health Service, Washington, D.C.

In the absence of Mr. Wieters, this paper was presented by L. F. Warrick, Chief, Tech. Service Branch, Div. of Water Pollution Control, U. S.P.H.S., Washington, D.C. Mr. Warrick told how the Pub. Health Service had been working with the states during the past year and a half in the development of comprehensive programs for water pollution control throughout the country.

The speaker emphasized the cooperative nature of the efforts designed to cover the ten major drainage basin areas. The first step was to assemble data for summary reports on the several major drainage basins. These summary reports will contain information on the sources

and effects of pollution and recommendations for construction based on currently known requirements.

At present, there is knowledge of more than 22,000 significent sources of pollution, including approximately 11,800 cities and 10,400 industries. The municipal sewage load comes from a sewered population of 92 million persons. Some degree of treatment is provided at 6,700 cities having a population of 56 million. Of the industries, 2600 have treatment of some kind, 3600 are known to be untreated, and for 4000 industries no information is available.

In the overall picture at least 6500 new municipal plants are needed and 3500 need additions or replacements, and at least 3500 industries are known to need new plants, while 5500 plants have yet to be assessed as to needs.

Mr. Warrick reviewed briefly the work of the WPCAB, the National Technical Task Committee in Industrial Wastes and the publication of a popular type educational booklet, "Water Pollution in the United States." The Pub. Health Service has also reprinted portions of the report of the President's Water Resources Policy Commission.

Ind. Stream Pollution Board

"A Stream Pollution Control Hearing," by R. B. Wiley, Head, School of Civ. Engr. and Engr. Mech., Purdue University, Lafayette, Ind.

Prof. Wiley, who is one of the two engineer members of the Ind. Stream Pollution Control Board, reviewed briefly the history of stream pollution control in Indiana beginning with the passage of the first bill in the early '30's and its reversal in 1939, followed by a new act in 1943, which set up a board with regulatory powers. Now there is a 7 man board bipartisan in nature, with the Chief Sanitary Engineer of the state acting as technical secretary.

The sanitary engineering division of the state board of health is the technical arm of the board and does all of the engineering and laboratory work. The board, therefore, has no worry about monies to carry on surveys, etc.

According to the act setting up the agency, the board has the power to control pollution and can define pollution. Since it is unlawful for a municipality to pollute a body of water, the board can order the municipality to cease pollution, after a hearing at which the facts are present. The city may appeal to the court which cannot hear further evidence, but merely decides on the reasonableness or unreasonableness of the order.

In Indiana, the philosophy exists that there are certain basic standards but no universally applicable yardstick for pollution. Thus the board can consider each situation on its own merits and the conditions involved. It has steadfastly refused to classify streams.

Prof. Wiley reviewed the steps of a hearing, which is held according to a uniform procedures act. He explained how the hearing is held as a court case, with evidence, witnesses, cross examination, etc. The hearing is held before one member of the board who reports to the whole board which then acts on the issuance of a cease pollution order. The board cannot issue such an order without a hearing, but a municipality can not object to the order because it has no funds; it can issue revenue bonds.

Atomic Energy Wastes

"Waste Disposal Problems in the Atomic Energy Industry" by Arthur E. Gorman, Sanitary Engineer, Division of Engineering, Atomic Energy Commission, Washington.

Mr. Gorman pointed out that wastes from atomic energy operations differ from wastes of other industries. They may be toxic or radioactive or both; they may be liquid, solid or gaseous, and they differ from one plant to another. In the case of radioactive wastes, the life of radioactivity is important in the matter of disposal.

The phenomenon of fixation of radioactivity to solid surfaces is under study because it affects methods of disposal. Equipment used in operations may become radioactive and thus have to be wasted (i.e. disposed of). Studies are in progress in several laboratories on the effects of various normal water and waste treatment processes on radioactive wastes. Ordinary water softening or coagulation appears effective in removing radioactive particulates from waste waters but sludge may have to be dried and buried or disposed of at sea.

All of the efforts of the researchers on this subject are being directed toward reducing radioactivity of all types of wastes to normal background levels before the wastes are discharged to the air, to streams, or to the soil. The best sanitary engineering laboratory is now at the Laboratory at Los Alamos. Important work is also being done at the Laboratory of the USPHS at Cincinnati.

Mr. Gorman listed a dozen other laboratories at universities and federal agencies which are now studying the several problems of waste disposal. These investigations include: Effect of long reservoir storage on radioactivity, air cleaning methods, water borne silt, estuary effects, plumbing, air diffusion, effect of orthodox methods of water purification for decontamination, sewage treatment processes, meterology, package type incinerators, surface attachment, gas filters, etc.

Progress to date is encouraging according to Mr. Gorman, who said that the atomic energy industry needs sanitary engineers.

(*Continued in next issue*)

C. H. Beckert
Director
Wat. Resources
St. Consv. Dept.
Indianapolis, Ind.

Jack Gordon
Supt.
Water Dept.
South Bend,
Ind.

Presiders

Earnest Boyce
Chairman
Dept. Civ. Engr.
Univ. of Mich.
Ann Arbor, Mich.

D. P. Bachmeyer
Supt.
Water & Sewage
Marion,
Ind.

H. S. Kline
Ind. Hyg. Engr.
Frigidaire Div.
Gen. Motors Corp.
Dayton, O.

Sound Practices In Sewer Construction

by FRED S. CRESSWELL, *C. E., Manager, National Clay Pipe Mfgrs., Inc., Washington, D.C.*

TO develop maximum capacity and strength in sewer construction, materials, as well as workmanship, should be of the highest quality. One without the other is of little benefit to the finished project, and the difference between eminent success and outright failure hinges on the degree of attention given each.

Good Trenching

Mechanical equipment that is not suited to the specific job is too frequently used to complete sewer installations in the shortest time possible. Such time-saving methods frequently result in subsequent costly replacement of the line. Sound sewer systems begin with proper trenching procedure.

Above all else, the trench should be no wider than necessary to accommodate the pipe and provide sufficient space for completing joints. If possible, this practice should be carried to the top of the trench, but in any event trench widths should be restricted until the level of the pipe top is reached. Failure to comply with this requirement will overload the pipe unnecessarily and result in failure of the sewer. As a general rule it should be possible to restrict trench widths to the outside barrel diameter of the pipe plus 12 inches, thereby providing 6 inch wall clearance on each side of the pipe.

Excavation should be carried only as deep as is absolutely necessary. If mechanical equipment is employed, the trench should be manually excavated from a level of four inches above invert grade to the bottom of the trench, thereby insuring stable foundation conditions.

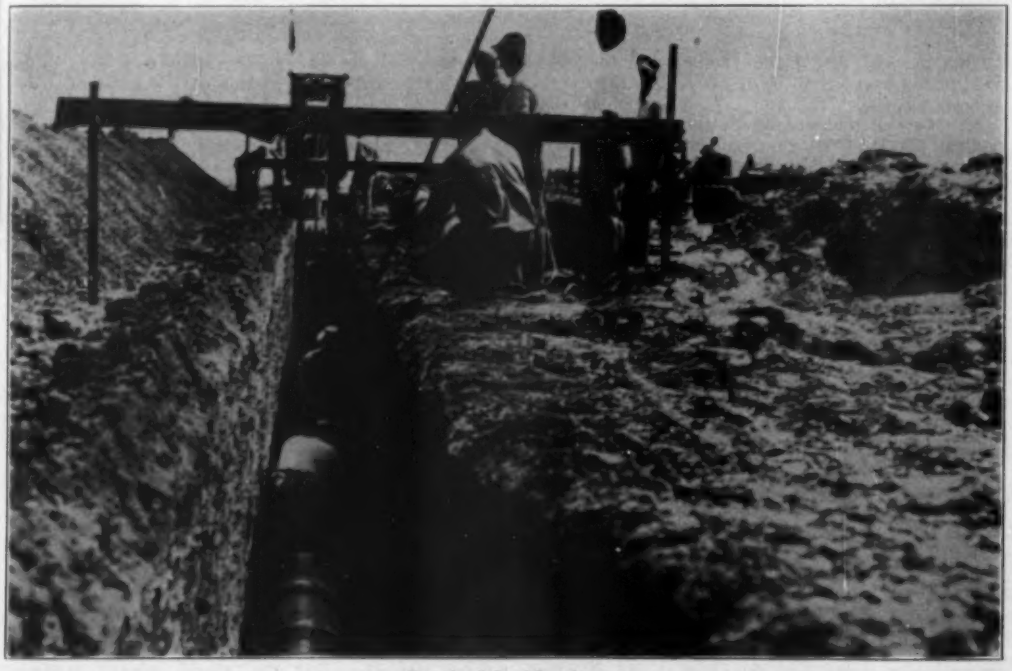
Earth Trenching and Trenching Machines

Except for small jobs, hand trenching will be found inefficient and uneconomical. In ground that is free of heavy obstructions and not too hard, the modern trencher is very efficient. Most of the early trenching machinery, first perfected about 1910, has given way to the modern ladder and wheel type trenchers. Local conditions determine the type of trencher best suited for the particular installation.

Many construction men and contractors consider the wheel type trencher a harder digger than the ladder type. Wheel types however are generally limited in maximum widths and depths, the maximums being about 3½ feet in width and 8½ feet in depth. If greater width and depths are required, the ladder type trencher must be used.

Another type of mechanical equipment being given widespread use is the machine commonly known as the backhoe. This piece of equipment is well suited to sewer construction provided the width of the hoe is not too great. One of the hazards of mechanical excavating equipment for sewer trenching is the tendency to excavate to excessive widths thereby reducing the stability and structural strength of the line.

In tight sheeted deep trenches it is sometimes necessary to employ hand

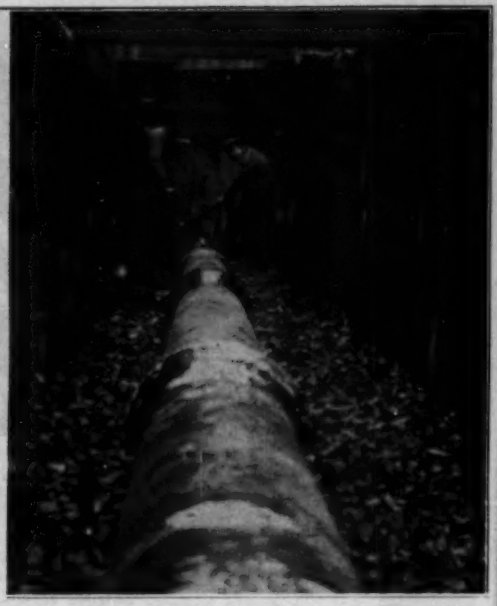


Example of Good Trenching

Machine cut; straight walls; solid bottom hand levelled; width held to about six inches on each side of pipe, providing ample working space for good jointing.

Good Backfilling Practice

Note narrow trench to level above top of pipe. To prevent lateral movement backfill is brought up evenly under haunches of pipe and tamped. No water is used to settle fill.



Good Bedding Practice

When natural trench bottom is likely to be unstable, the trench is dug deeper and the pipe laid on a 6 in. bed of gravel or crushed stone to provide uniform non-shifting bearing.

labor although in many cases clam shell buckets can be used advantageously. Also in the case of deep trenches where soil conditions are unstable it is desirable to employ staging platforms as well as sheeting in order that the workmen can use the platforms in driving the lower sets of sheeting as well as in removing the excavated material.

In cases where trenches are rather deep and soil condition relatively stable it is helpful to use skeleton sheeting and stay bracing. By so doing the lives of the workmen are protected and excessive slippage of soil into the bottom of the trench is prevented.

Rock Trenching

No preferred method can be set up as model practice in rock trenching. The type and quantity of rock will usually determine the method of excavation best suited to obtain a good trench.

Different methods of drilling and shooting must be employed as the various rock formations are encountered. Granite and other dense strata will naturally require closer spacing of holes than will the softer formations.

After the rock has been shattered by blasting, a pull shovel, drag-line, or trench-hoe may be employed for trenching. Except in very soft formations, the use of ladder type trenchers is not practical.

If the rock is removed by hand, as is practicable in shallow trenches, it must be broken into small pieces by blasting, or the use of sledge hammers or air hammers.

The use of a drag-line or pull shovel is most economical for deep rock trenches. However, the rock must be thoroughly broken up prior to removal by the shovel. Rocks too large for the bucket should be hoisted from the trench by use of chains or other suitable handling equipment.

Bedding Clay Pipe

In bedding clay pipe, the barrel of the pipe should rest uniformly in a "form fitting" trough prepared throughout the bottom of the trench. The soil below invert grade should be left intact, if bedding conditions are stable and dry.

If the soil in the trench bottom is not suited to uniform bearing because of rock or unstable earth, either or both should be removed by carrying the excavation at least six inches below invert grade. Material of uniform gradation and unyielding nature such as gravel or crushed stone should be added to insure a bottom that will provide uniform bearing for the entire bottom gradrant of the pipe barrel.

In some cases, a concrete cradle may be necessary to obtain a proper foundation. If extremely fine wet soil is encountered, it can be stabilized by driving wall sheeting well below invert grade and adding coarse aggregate until the desired stability is reached.

Bell holes must be provided at proper intervals so that no part of the load is supported by the bells. Each length of pipe should be checked as it is placed to see that the bells "hang free" and that proper slope and alignment are insured.

Jointing

Before any joints are made, the socket and spigot ends of clay pipe should be thoroughly cleaned *and dry*. Likewise the trench bottom should be free of water. It must be remembered that good joints cannot be made under wet conditions.

Several types of joints are satisfactory, but workmanship, in all cases, is extremely important. A sufficient period must be allowed for the jointing compound to become fully set and completely water-resistant.

Steps in jointing clay pipe are:

1. Wipe bell and spigot clean and dry to assure tight bond of compound.
2. Pack oakum firmly into joint to center spigot and seal bottom of joint. It is recommended that the joint space be filled with dry oakum to ⅓ of its depth.
3. Clamp runner or "snake" tightly against bell. Seal leaks with moist

clay. Keep the "gate" or opening slightly off center so that compound will flow around the pipe in one direction. Pouring off center is good insurance against voids forming in the compound.

4. Pour the joint quickly, with the compound as fluid as possible. Always follow exactly the recommendations of the manufacturer of the compound as regards pouring temperature, method of heating and other requirements. Be sure to completely fill the joint.

Much time can be saved by pouring alternate joints with the pipe in a vertical position on the top of the trench. Pack firmly with oakum as before. No runner or "snake" is needed. This recommendation is restricted to the smaller pipe sizes for reasons of ease in handling. To insure perfect alignment and joint tightness multiple sections can be lowered in the trench by use of a straight 2x4 or 4x4 inserted inside the pipe and extending beyond both ends.

The essentials of a good joint are:

1. It must be water-tight.
2. It must be acid and alkali proof.
3. It must form a strong and permanent bond with the surface of the pipe.
4. It must retain sufficient plasticity to insure flexibility.
5. It must be easy to make. Several hot-poured jointing compounds and methods on the market today satisfy these conditions.
6. It must be root resistant.

All disturbance of the line should be avoided until backfill has been placed. Water should not be permitted to come in contact with the joints until they are properly set. In order to prevent disturbance of the line workmen should not be allowed to walk or work on top of the pipe until after the joints have set and until backfill has been tamped under the haunches and up the sides to the top of the pipe.

Socalled "Diaper Joints"

Often cement joints of the larger diameters of clay pipe are protected with "diapers" to insure slower setting and protect joints during backfilling.

Backfilling

An important phase of any sewer construction is the proper placing of backfill. Excavated earth is suitable in most instances for backfilling purposes. However, if any frozen material or large rocks are present, the earth should be carefully screened to insure complete removal before it is replaced.

As soon as inspection is complete, backfilling should begin. Any sheeting extending below the top of the pipe should *not* be withdrawn, since removal will cause voids which may in turn displace the pipe. The backfill should be added in six-inch layers and tamped solidly to prevent lateral movement of the pipe. Tamping should be continued until a level of two feet above pipe top has been reached. The remainder of the backfill should be uniform and placed so that no unbalanced loading occurs. As a general rule, from a point 2 feet above the top of the pipe to the top of the trench, the backfill can be placed in layers of about 18 inches, each layer being separately tamped.

Avoid Use of Water

Filling the trench with water as the backfill is placed is a very objectionable and unacceptable practice and is not recommended as effective or advantageous. Some water may be added only in the case of gravel or sand backfill but even in these cases great care must be exercised to see that only the minimum amount required is used.

In heavily travelled streets it is recommended that traffic be kept off the newly filled trench for at least 48 hours, thereby providing sufficient time for proper natural consolidation. This precaution will prevent disturbance of the line and assure years of trouble free service.

Good Backfill Consolidation Practice

In this day of heavy traffic impact it is good practice to maintain the barricade as long as permissible before final backfill or repaving. Thus, maximum natural settling and condensation of material is secured prior to paving. Flooding of trench with water is not desirable, for reasons pointed out in text.

CHICAGO SEWAGE EQUIPMENT

Specifically designed and engineered for comminution and grit removal; for activated sludge sewage treatment plants; for sewage digesters and for pumping sewage and sludge.

READ the Four pages of facts about CHICAGO sewage equipment in the Reference and Data section.

Meetings Scheduled:

Apr. 5-6—Old Point Comfort, Va. *(Hotel Chamberlain)*
VIRGINIA INDUSTRIAL WASTES & SEWAGE WORKS ASSN. Sec'y, A. H. Paessler, 815 E. Franklin Street, Richmond 19, Va.

Apr. 5-6—Albany, N.Y. *(Hotel Ten Eyck)*
NEW YORK SECTION A.W.W.A. (SPRING MEETING). Sec'y, Rollo K. Blanchard, 50 West 50th Street, New York 20, N.Y.

Apr. 9-11—Hot Springs, Ark. *(Majestic Hotel)*
ARKANSAS WATER & SEWAGE CONFERENCE. Sec'y, Harrison Hale University of Arkansas, 118 Chemistry Bldg., Fayetteville, Ark.

Apr. 11—Orono, Me. *(University of Maine)*
MAINE WATER UTILITIES ASSOCIATION. Sec'y, Earle A. Tarr, Supt. Water District, Winthrop, Me.

Apr. 11-13—Hays, Kansas *(Lamar Hotel)*
KANSAS SECTION A.W.W.A. Sec'y, H. W. Badley, 640 Highland St., Salina, Kans.
KANSAS SEWAGE WORKS ASSOCIATION. Sec'y, Dwight F. Metzler, State Board of Health, Univ. of Kansas, Lawrence, Kans.

Apr. 16-19—Madison, Wis. *(University of Wisconsin)*
12TH SHORT COURSE FOR SEWAGE PLANT OPERATORS. Gerard A. Rohlich, Director, College of Engineering, Univ. of Wisconsin, Madison 6, Wis.

Apr. 19—Storrs, Conn.
NEW ENGLAND WATER WORKS ASSOCIATION (Joint meeting with) CONNECTICUT WATER WORKS ASSOCIATION. Sec'y, Jos. C. Knox, 73 Tremont Street, Boston 8, Mass.

Apr. 19-20—Lincoln, Neb. *(Cornhusker Hotel)*
NEBRASKA SECTION A.W.W.A. Sec'y, E. Bruce Meier, 201 Mechanic Arts Bldg., Univ., of Nebraska, Lincoln, Neb.

Apr. 19—Helena, Mont. *(Hotel Placer)*
MONTANA SEWAGE WORKS ASSOCIATION. Sec'y, H. B. Foote, State Board of Health, Helena, Mont.

Apr. 20-21—
MONTANA SECTION A.W.W.A. Sec'y, Arthur W. Clarkson, State Board of Health, 1036—8th Ave., Helena, Mont.

Apr. 25-28—Fresno, Calif. *(Hotel California)*
CALIFORNIA SEWAGE WORKS ASSOCIATION. Sec'y, Lawrence H. Cook, Box 696, Menlo Park, Calif.

Apr. 29-May 4—Miami, Fla.
AMERICAN WATER WORKS ASSOCIATION. (Annual Convention.) Exec.-Sec'y, Harry E. Jordan, 500 Fifth Avenue, New York 19, N.Y.
(Meetings and Exhibits in the Dinner Key Auditorium.) Application blanks for hotel accommodations were mailed to members by the Association Headquarters in December. All reservations will be cleared through the A.W.W.A. office.

May 15-16—Vancouver, B.C., Canada *(Hotel Vancouver)*
PACIFIC NORTHWEST SEWAGE WORKS ASSOCIATION. Sec'y, Wm. P. Hughes, City Hall, Lewiston, Idaho.

May 17-19—
PACIFIC NORTHWEST SECTION A.W.W.A. Sec'y, O. P. Newman, Boise Water Department, Boise, Idaho.

May 17—Manchester, N.H.
NEW ENGLAND WATER WORKS ASSOCIATION. Sec'y, Jos. C. Knox, 73 Tremont Street, Boston 8, Mass.

May 21-23—Winnipeg, Man., Can. *(Alexandra Hotel)*
CANADIAN SECTION A.W.W.A. Sec'y, Dr. A. E. Berry, Ontario Department of Health, Parliament Building, Toronto, Ont.

June 4-5—Grand Rapids, Mich. *(Hotel Pantlind)*
MICHIGAN SEWAGE & INDUSTRIAL WASTES ASSN. Sec'y, Donald M. Pierce, State Dept. of Health, Room 334, Administration Bldg., Lansing 4, Mich.

June 7-8—Springfield, Mass. *(Hotel Kimball)*
NEW ENGLAND SEWAGE & INDUSTRIAL WASTE ASSN. Sec'y, Walter E. Merrill, State Dept. of Health, 511A State House, Boston, Mass.
(Joint Meeting)
NEW YORK SEWAGE & INDUSTRIAL WASTES ASS'N. Sec'y, Ralph C. Sweeney, 21 N. Broadway, White Plains, N. Y.

June 11-14—Tuscaloosa, Ala. *(University of Alabama)*
ALABAMA WATER & SEWAGE WORKS ASSOCIATION. Sec'y, Alex O. Taylor, Box 69, Auburn, Ala.

June 13—York Harbor, Me. *(Joint Conferences)*
MAINE WATER UTILITIES ASSOCIATION. Sec'y, Earl A. Tarr, Winthrop, Me.

NEW ENGLAND WATER WORKS ASSOCIATION. Sec'y, Jos. C. Knox, 73 Tremont St., Boston, Mass.
NEW HAMPSHIRE WATER WORKS ASSOCIATION. Sec'y, W. A. Healy, 17 Capitol St., Concord, N.H.

June 20-22—Columbus, Ohio *(Neil House)*
OHIO SEWAGE AND INDUSTRIAL WASTES TREATMENT CONFERENCE. Sec'y, J. E. Richards, 302 Departments Bldg., Columbus 15, Ohio.

June 29—Trenton, N.J. *(De Laval Steam Turbine Plant)*
NEW JERSEY SECTION A.W.W.A. (Summer Meeting.) (Inspection Trip and Luncheon.) Sec'y, C. B. Tygert, Box 178, Newark, N.J.

Aug. 20-22—Toronto, Ont. *(Royal York Hotel)*
CANADIAN INSTITUTE ON SEWAGE PURIFICATION. Sec'y, A. E. Berry, Parliament Buildings, Toronto, Ont.

Aug. 20-22—State College *(Nittany Lion Inn)*
PENNSYLVANIA WATER WORKS OPERATORS' ASSOCIATION. Sec'y, R. Rupert Kountz, Penna. State College, State College, Pa.

Aug. 22-24—
PENNSYLVANIA SEWAGE & INDUSTRIAL WASTES ASSOCIATION. Sec'y, B. S. Bush, Dept. of Health, Kirby Health Center, Wilkes-Barre, Pa.

Sept. 10-12—Boston, Mass. *(Hotel Statler)*
NEW ENGLAND WATER WORKS ASSOCIATION (Annual convention). Sec'y, Jos. C. Knox, 73 Tremont Street, Boston 8, Mass.

Sept. 11-13—Marshalltown, Iowa *(Hotel Tall Corn)*
IOWA SEWAGE WORKS ASSOCIATION. Sec'y, Leo Holtcamp, P.O. Box 310, Webster City, Ia.

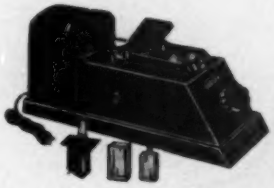
Sept. 12-14—Minneapolis, Minn. *(Hotel Nicollet)*
MINNESOTA SECTION A.W.W.A. Sec'y, Leonard N. Thompson, 216 Court House Bldg., St. Paul, Minn.

Sept. 17-19—Louisville, Ky. *(Kentucky Hotel)*
KENTUCKY-TENNESSEE SECTION A.W.W.A. KENTUCKY-TENNESSEE INDUSTRIAL WASTES & SEWAGE WORK ASSN. Sec'y, R. P. Farrell, 420 Sixth Ave., N., Nashville 3, Tenn.

(*Continued on page* 149A)

KLETT SUMMERSON
ELECTRIC PHOTOMETER

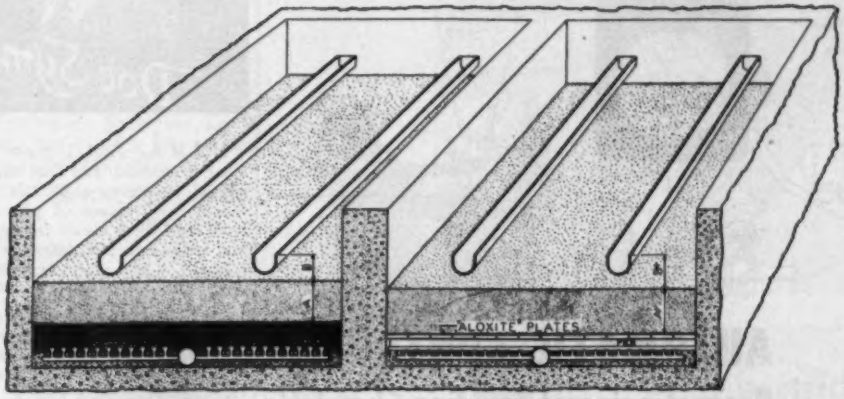
Adaptable for Use in Water Analysis



Can be used for any determination in which color turbidity can be developed in proportion to substance to be determined.

KLETT MANUFACTURING CO.
179 EAST 87th STREET • NEW YORK 28, N.Y.

Planning to rebuild old shallow filters?



BEFORE **AFTER**

***ALOXITE* underdrains offer "extra dividend" features.**

For operators of shallow filters, ALOXITE porous bottoms give all the basic benefits that follow elimination of graded gravel support. Moreover, they pay "extra dividends" by solving certain problems inherent in operating such units:

- When rebuilding old-style filters (see "Before") to get proper wash rates, these porous plates permit you to lower filter media. Back washing can then be stepped-up to use greater available distance (B+) to wash gutters. And with the "After" design you profit by a simultaneous increase in operating head for filtration. Where necessary, the filter media bed can be deepened (A+) as porous plate construction supplies a lot of added space.
- In designing new filters, topography may be such that available head is very limited and critical. Here the extra head provided by the construction of ALOXITE filter bottoms may solve the problem.

When seeking ways and means of improving your filters, don't overlook ALOXITE aluminum oxide porous plates. For shallow filters — or *any other type of filter* — underdrains of this type have proved to be distinctly superior.

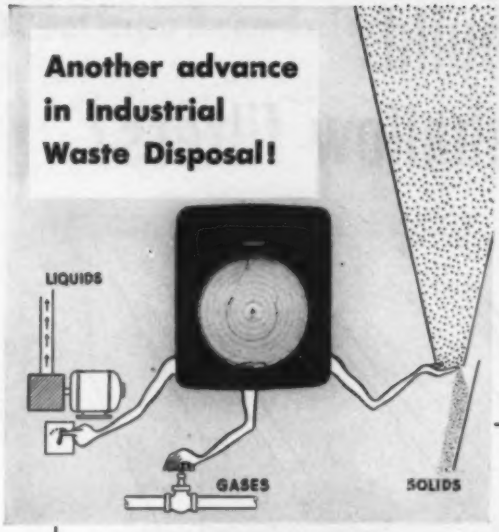
EVIDENCE: There are nearly 300 installations of ALOXITE filter bottoms in operation today — *some of which are in their 15th year of service!*

REASONS: You'll find them in our new 56-page booklet "Porous Media for Filtration and Diffusion." It's a complete reference handbook — contains a wealth of useful charts, graphs, and photos. A copy is yours for the asking.

THE CARBORUNDUM COMPANY

Dept. M-41, Refractories Div. Perth Amboy, New Jersey

"Carborundum" and "Aloxite" are registered trademarks which indicate manufacture by The Carborundum Company.



AUTOMATIC CONTROL for Proportioning of Treating Chemicals

Feeding of treating chemicals at rates proportionate to flow can *now be done automatically* — with total elimination of time-consuming, periodic adjustment of feeders and pumps. In addition, the proportioning of chemicals is far more accurate, which means a more uniform, satisfactory effluent and a definite saving in cost of chemicals.

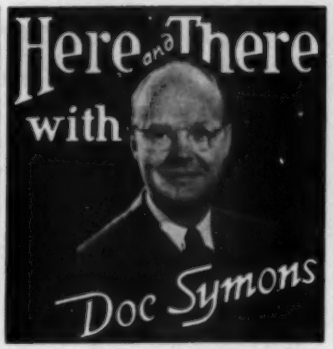
The instrument control system is properly engineered for individual plant conditions. Its design depends upon the quantity, corrosive quality, and viscosity of the activated silica, carbon dioxide, soda ash, lime, or other chemicals employed . . . also upon the amount of chemicals to be stored and the type of plant operation.

Virtually *any* set of conditions can be met with one or another of the following instrument control methods offered by Foxboro:

1. *ratio flow control with pneumatic control valves for liquid chemicals or gases*
2. *control of motor operation on dry feeders or on proportioning pumps by "pulse-time" control*
3. *motor speed control on dry feeders or proportioning pumps through electronic control of power input.*

One of these methods may bring substantial new economies to the operation of your waste disposal system. For engineering briefs on industrial waste surveys, chemical control systems, and disposal methods, write **The Foxboro Company, 2284 Neponset Ave., Foxboro, Mass., U. S. A.**

FOXBORO *Instrumentation*
INDICATING · RECORDING · CONTROLLING



H.T.M.A.—And I guess I don't need to remind you that this is the annual Reference and Data issue of *W. & S.W.* Some of you, I know, have kept these issues for years back and for your benefit, the current issue contains a five year consolidated index.

Some of those older articles are still good even though they haven't been republished since and you should have the last three or four handy, for there's a lot of good stuff in 'em.

* * *

Last month I opened the column with musing about how long I'd been doing "Here and There." This month, I thought maybe you'd like to know just how I go about writing one of these "letters"—

It sounds easy—just to write a letter every month—doesn't it. It is; I just sit down, stuff a sheet of paper in the typewriter, pull out some notes, and the letter writes itself.—All I have to do, is to make it sound as though I were talking to you; trim the items to fit the space; refrain from editorializing—too much, that is—; interpose some candid shots here and there, throw out several stories that don't sound half as funny as they did when they happened—and the first draft is done.

Next day, I'm in a different mood; the letter doesn't sound right; I remember that it will be six weeks before you see it; it has to be reorganized to make it timely, then cut some more to fit the probable space available.—Now to retype it; think up a tag line, correct the typing mistakes, mark it for the printer, and mail it to Mt. Morris, Ill.—About a thousand words—a good hour's work—and it's taken me the better part of two days to do it.

Ten days later, I find that several items I wrote for the previous month didn't get in (especially the ones I had definitely promised someone),

and the current column has to be reorganized again to fit in the left-overs. By then I'm ready to say, "Oh! Whazause!" But, come some meeting and one of you says to me, "I always read your column" and—I'm rarin' to go on another one.—Sucker!

* * *

And now to get back to the Federation Meeting in Washington, D.C., last October—We're not through with that yet.—

I was having my semi-annual tuna-fish sandwich and coke lunch with F. W. (Kit) Kittrell of T.V.A., when he offhandedly said something about doing a caricature. Right then, I commissioned him to do a few for this column. Here's his first—

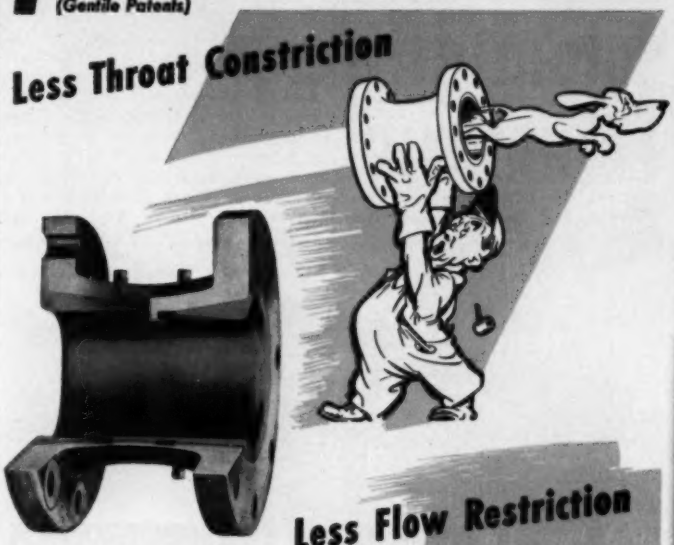
Don Bloodgood (of the Purdue Bloodgoods) swears this happened to him. He had boarded the train for Washington while Purdue was in the process of battling Notre Dame's unconquerable football team, and he didn't know the game's outcome when he arrived at the Statler Hotel on Sunday morning. No sooner had he set foot in the hotel lobby that morning, when a Michigan man fell on his knees and fervently thanked him for Purdue's victory over Notre Dame. —I don't recognize the man on his knees—Could it have been Larry (Mich Stream Poll.) Oeming from Lansing?

* * *

On the Sunday evening before the Federation meeting, the dazzling Norma (Mrs. Harry) Schlenz, (he's Vice Pres. of PFT) held a cocktail party for the members of the Board of Directors and their wives.—Well sir, it was old home week for Arkansas—Some one mentioned the Iron Mountain Railroad and Hilltop, Ark. and right away, H. Vance (Gen. Elect.) Crawford spoke up—*he* not only knew where it was, but he was born in "them" parts.

FOSTER FLOW TUBE*

(Gentile Patents)



Study the above picture of the Foster Type V Flow Tube which operates on the viscous drag principle. Note the almost straight-through construction. There's only a slight throat constriction. And the same minimum throat constriction is typical of the Type D Flow Tube which operates on the principle of dynamic impact. *Both types offer minimum resistance to flow.*

You know what this means. Negligible unrecovered head loss in the flow of the liquid or gas. Less power required to push it along.

"Good," you say, "but what about accuracy?"

The Foster Flow Tube will measure the flow of liquids or gases with an accuracy at least comparable to that of conventional primary devices and, in most cases, with considerably greater accuracy, because it can readily be installed in that section of the hydraulic system where flow conditions are uniform and steady. Thus, with this unique Flow Tube, you can combine accuracy with neglible head losses—accuracy with compactness—accuracy with ease of installation.

Write us in detail about your problem, giving both processing and installation requirements. We have several types and units in all commercial pipe sizes.

*A Proved Flow Tube Added to Foster Line of Regulating Valves

FOSTER ENGINEERING Company

825 Lehigh Avenue • Union, N. J.

PRESSURE REGULATORS ... RELIEF AND BACK PRESSURE VALVES ... CUSHION CHECK VALVES ... ALTITUDE VALVES ... GAS SNUBBER REGULATORS ... PUMP GOVERNORS ... TEMPERATURE REGULATORS ... FLOAT AND LEVER BALANCED VALVES ... HYDRAULIC VALVES ... VACUUM REGULATORS OR BREAKERS ... STRAINERS ... SNUBBERS ... SAFETY VALVES ... FLOW RATE

In the group at the time were Mrs. Crawford, Mr. and Mrs. Hollis R. Conway (he's Sr. San. Engr. with the Ark. Bd. of Health); Carl Wright of PFT, Art Niles (Toledo's Man About the Sewage Plant and then Prexy of FSIWA) and I. And whad'ya know—every one of 'em had been born in Arkansas except Very Truly Yours,—the only Sucker in the bunch.

* * *

It was also at the Fed. Meeting in Wash. that I met two of my prettiest readers: Beth Soderholm, Chief Chemist, and Blanche Glenn, Asst. Chemist, both of the Virginia State Water Control Board in Richmond. —WOW ! ! !

* * *

WATER WORKS ROMANCE No. 14—Some of you know that Mrs. William S. Wise (he's Chief Engr. of the Water Commission of Connecticut) and I share a similar interest in the works of Shakespeare. We are both also interested in the story of her romance, and I think you will be, too.

A few decades back, Wm. R. Copeland was Chief Engineer of Hartford, Conn., and his young assistant was a fellow named "Bill" Wise, who had an eye for figures, engineeringwise as well as for that of a new secretary Mr. Copeland had just hired. She was a mighty sweet young thing, and an excellent stenographer but not too well versed in the language of the sanitary engineer.

One day, Mr. Copeland dictated a long report, which she dutifully and correctly transcribed. Not being too sure of some of the terminology, that night at dinner she asked Bill, "What kind of a bird is a privy?" To which "Bill" replied, "WHAT!"—"Well," she said, "Mr. Copeland dictated a whole paragraph about a 'privy perched on a river bank' "—

So, "Bill" asked her to marry him—and he's been educating her ever since.

Incidentally, it was this same Wm. R. Copeland who was Chief Chemist at Columbus, Ohio, in 1908 and whose two assistants were the late Charlie Hoover (longtime Supt. of Filtration at Columbus) and Walt Sperry, Supt. of Sewage Treatment at Aurora, Ill. —(to whom I am indebted for this story.)

* * *

For a long time now I've been promising you some pictures of sundry members of the Wisconsin AWWA Beanie Club and here they are. One Zenno Gorder (Dir. Pub. Wks., Monroe, Wis.) and Prexy Par Excellence of the Club provided these, taken at the Wis. Section Meeting this past fall.

Here, first, you see Tom McGuire of Plymouth, (Chairman of the Wis. Sect.); Dr. John Schindler, guest speaker at the meeting, and Zenno (The Prez, himself) Gordo.

Next, below, is that peerless Waukesha Water Boy—Art Kuranz and the famous Francis Cunningham

(Neptune Meter) of Milwaukee, who thinks Ann Shaw (in Harry Jordan's N.Y. Office) enhances an orchid.

CENTRILINE

CONFORMS STRICTLY WITH A.W.W.A. SPECIFICATIONS

▶▶▶PIPE LINING FACTS NO. 3

▶▶▶▶ The Standard Specifications for cement-mortar protective coatings issued by the American Water Works Association provide: "Interior of the entire line, including both curves and tangents, shall be by centrifugal machine . . . the machine shall apply the mortar by centrifugal action without the use of compressed air and follow its application by automatic trowelling to a uniform thickness and smooth finished surface."

The strict adherence to these specifications by Centriline insures a continuous, dense, smooth lining—applied without rebound—that means restored carrying capacity perpetually sustained and longer life to mains. If pipelines are losing efficiency it is time to consider Centrilining. Our engineers stand ready to assist you, without obligation.

▶▶▶▶ WRITE TODAY FOR THE 28 PAGE CENTRILINE CATALOG

CENTRILINE CORPORATION

A subsidiary of Raymond Concrete Pile Co.

140 CEDAR STREET • NEW YORK 6, N.Y.

Branch Offices in all Principal Cities in the United States and Latin America.

American Pipe & Construction Company of Los Angeles, Calif. (P.O. Box 3428, Terminal Annex) Licensee Western Part of U. S.

Reg. U. S. Pat. Off.

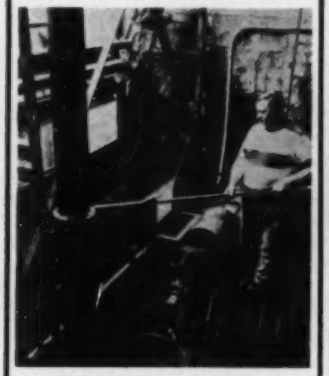
CEMENT MORTAR LININGS FOR WATER MAINS

Centrifugally Applied in Strict Conformity with A.W.W.A. Specifications

"Since 1885"

Twice the choice

of the DEPARTMENT of PUBLIC SANITATION EAST CHICAGO, IND.



Latest Gruendler Screenings Shredder at the Alder Street Pumping Station of East Chicago, Ind.

1947 . . .

Gruendler SEWAGE SCREENINGS SHREDDER, installed in 1947.

1950 . . .

Gruendler SEWAGE SCREENINGS SHREDDER, installed in 1950.

Sewage and Garbage Shredders built for Municipalities, large or small.

Detailed Specifications and Suggested Installation Drawings furnished for any size Plant. Write to Waste Disposal Department . . .

GRUENDLER CRUSHER and PULVERIZER CO.

2918 North Market ST. LOUIS 6, MO.

This fellow, below, is Leon (Bridge Expert) A. Smith, long time Secretary of the Section and Madison's Water Maker.

And this debonair bon vivant is, of course, Vic (AWWA Prexy) Weir of St. Louis County Water Co.—

Smiling, no doubt, because he is flanked by Mrs. Leon A. Smith left and Mrs. Tom McGuire, right.

Some of you readers will be seeing this headgear at the Miami Convention at the end of this month, and I'll be wearing mine as Charter No. 10. The Club now has 48 members, double the original number.

* * *

Through "Bob" (Mathieson Chemical) Quinn of Baltimore, you readers and I have been warned to watch for the "Thing" at Miami. Bob's warning read as follows:

"Dear Doc—

"Last month while enjoying my vacation in Tucson, Ariz., I was sitting in the lobby of the Pioneer Hotel when a young tornado breezed in wearing the biggest hat that ever came out of Texas. This tornado was surrounded by bellboys and other attendants, who solicitously referred to the newcomer as 'Senator.'

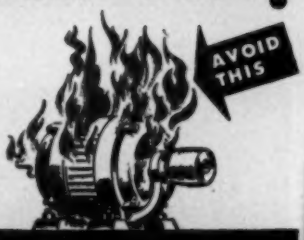
"Upon closer investigation, I found that it was none other than our old friend, Fred (Infilco) Eidsness—who should henceforth be addressed as 'Senator.'

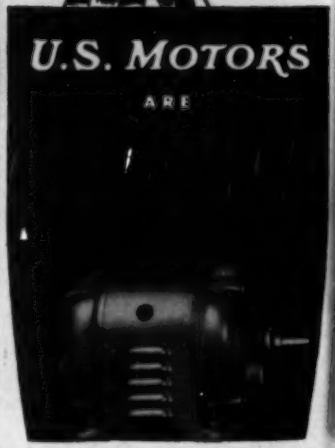
"I will make a little bet with you that the next time you see him, he will be wearing the 'Thing.'—Sincerely, Bob."

* * *

I'm sorry, I can't give you the low down on *the* places to eat while you're in Miami. I'd suggest that you ask C. F. (Dutch) Wertz of the Miami

"fed up" with motor burnouts?





ASBESTOS CANNOT CARBONIZE

Life of a motor is proportional to life of insulation protecting its windings. Only in U. S. Motors are windings *asbestos-protected* – insurance against costly burnouts. At no extra cost you get extra years of dependable motor life.

¼ to 250 h.p.

US MOTORS

U. S. Electrical Motors, Inc. WSW-4
300 E. Slauson Ave., Los Angeles 54, Calif.
or Milford, Conn.

Send Bulletin describing U. S. Unsleeved Motors and Asbestos Protected Windings.

Name_____

Company_____

Address_____

City_____ Zone___ State_____

Water Dept. or Joe (with the beautiful wife) Williamson of Russell & Axon, Cons. Engrs., for up-to-the-minute information.

On the other hand, part of my girl Gin's family lives in Lake Worth, not too far away and from them I can get you the dope on the Palm Beach area, if you're interested.

I can also tell you; if you're driving and pass through Smyrna, Ga. (about 15 miles outside Atlanta), you should stop at Aunt Fanny's Cabin for some *Ham with Red Gravy*, assorted side dishes and wonderful desserts—Hmmm—Good!—Second and third helpings free—Lunch about $2 and dinner roughly twice that.—No cocktails.

* * *

Well, Gee Whiz!—No more time this month; but next time we get together, look for a story from Jack Hinman, another on Don Bloodgood, Kit's Karicatures, and a contribution from Dr. Heukelekian, among others. —Hope you enjoy Miami.

V.T.Y.—Doc.

For Treatment of

SEWAGE and INDUSTRIAL WASTES

Specify

SOLVAY

TRADE-MARK REG. U.S. PAT. OFF.

LIQUID CHLORINE

SODA ASH

CALCIUM CHLORIDE

Write today for these Solvay Technical and Engineering Bulletins. They're available on request; no cost or obligation.

Bulletin No. 7—"Liquid Chlorine"

Bulletin No. 8—"Alkalies and Chlorine in the Treatment of Municipal and Industrial Water"

Bulletin No. 11—"Water Analysis"

SOLVAY SALES DIVISION

ALLIED CHEMICAL & DYE CORPORATION

40 Rector Street, New York 6, N. Y.

BRANCH SALES OFFICES

Boston · Charlotte · Chicago · Cincinnati · Cleveland · Detroit · Houston
New Orleans · New York · Philadelphia · Pittsburgh · St. Louis · Syracuse

Soda Ash · Caustic Soda · Caustic Potash · Nylrao · Formaldehyde
Calcium Chloride · Sodium Nitrite · Chlorine · Potassium Carbonate
Sodium Bicarbonate · Specialty Cleansers · Ortho-dichlorobenzene
Para-dichlorobenzene · Monochlorobenzene · Methanol
Ammonium Bicarbonate · Ammonium Chloride

SOLVAY Alkalies Chemicals 70 YEARS OF SERVICE 1881 1951

The Spillway

(Overflow From The Main Section)

New Use for Water Tank

Onaga, Kansas, had been moaning its fate because of the remoteness of this community from a TV station, and the lousy Television reception by Onaga's few TV sets.

Then one day a bright idea struck home. Onaga had a nice shiny new water tank on a 100 ft. tower. Why not? Atop the tank went a TV antenna projecting 25 ft. into those TV waves, above the water tower. The rest was simple enough. A coaxial cable now pipes TV into the homes of Onaga residents from the water tower, just as the water pipe system pipes in H_2O.

We understand that tall Master Antenna Stations have been erected in other communities distant from TV stations but this is the first (and we would bet not the last) case in which the municipal water tower has been put to the dual service of distribution of Video as well as H_2O.

Most Effective Advertising In 1950 Being Spotlighted

Judges have completed their selection of prize-winning business paper advertisements in the 1951 competition sponsored by the Associated Business Publications, of which *Water and Sewage Works* is a member.

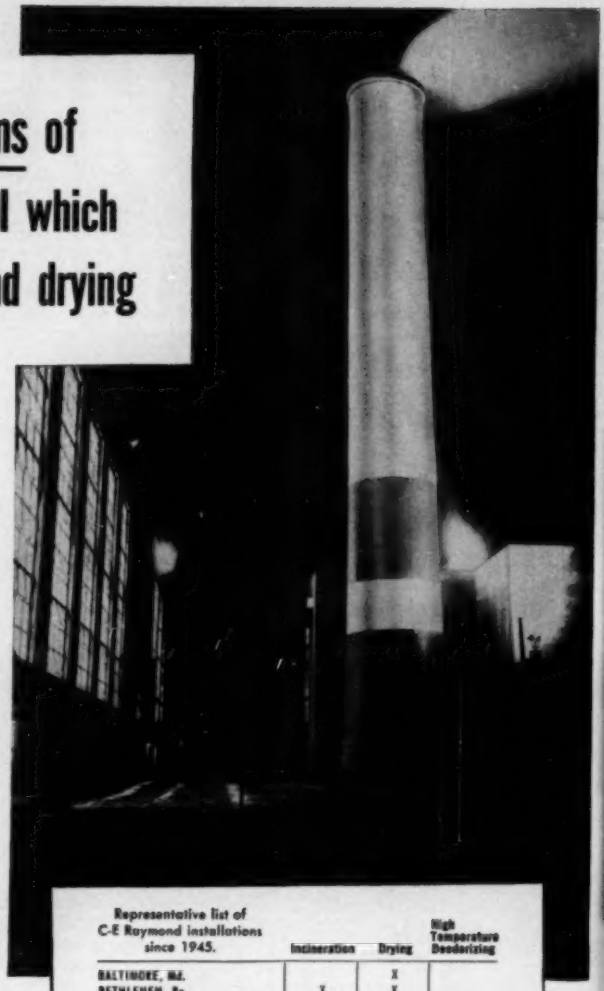
The 52 winners, examples of advertising campaigns that made the most effective use of their space in business papers during 1950, were chosen from 800 campaigns entered by advertisers and agencies in two separate contests —one for advertising in industrial, professional and institutional papers, and one for advertising in merchandising papers.

The judging of the Industrial Contest was held in Pittsburgh by a panel of 17 judges, under the chairmanship of Ernest T. Giles, Vice-President, Ketchum, MacLeod & Grove, Inc., and Chairman of the Pittsburgh Industrial Advertising Council's Educational Committee.

The presentation of plaques and certificates to prize-winning companies and their advertising agencies will

(*Continued on page* 124A)

the only proven means of Sewage Sludge Disposal which combines incineration and drying



As will be seen by the list at the lower right, there have been seven major installations of C-E Raymond Systems in the last five years which combine the two usual disposal methods . . . drying and incineration. The C-E Raymond System usually provides for high temperature deodorizing employing preheater equipment to save fuel and assure low stack temperatures.

C-E Raymond Systems installations are in service in virtually all parts of the country, meeting the varying requirements of both large and small communities. They are flexible in layout, highly efficient and thoroughly reliable; they provide for maximum utilization of waste heat.

A major reason for the success and widespread acceptance of C-E Raymond Systems is the exceptional background of experience represented in their design and manufacture. The Raymond Division has long been a recognized leader in the fields of grinding and drying, and Combustion Engineering—Superheater, Inc. has enjoyed similar standing in the combustion and heat recovery fields. The services of C-E specialists are available to assist you in finding the best solution to your sludge disposal problem. B-464

Representative list of C-E Raymond installations since 1945.	Incineration	Drying	High Temperature Deodorizing
BALTIMORE, Md.		X	
BETHLEHEM, Pa.	X	X	
CHICAGO, Ill. (W. Southwest)	X	X	
FOND DU LAC, Wis.		X	X
HOUSTON, Texas		X	
LOS ANGELES, Calif.	X	X	X
SAN DIEGO, Calif. (Extension)		X	X
SAN FRANCISCO, Calif.		X	X
SCHENECTADY, N. Y.	X	X	X
SHEBOYGAN, Wis.		X	X
WATERBURY, Conn.	X	X	X
COLNE VALLEY, England	X	X	X
RECIFE, Brazil		X	
WASHINGTON, D. C.	X	X	

Industrial sludges a problem?

C-E Raymond Flash Drying and Incineration Systems have been the answer for others. Write for information.

C·E

COMBUSTION ENGINEERING—SUPERHEATER, INC.

FLASH DRYER DIVISION

1315 North Branch Street, Chicago 22, Illinois

Western Offices: San Fernando Bldg., Los Angeles 13 — Eastern Office: 200 Madison Ave., N. Y. 16

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT

(Continued from page 122A)

be held in cooperation with the Pittsburgh Industrial Advertising Council in Pittsburgh's University Club on April 5.

In ABP's contest for advertising in merchandising papers, winning campaigns were selected in New York under the chairmanship of Raymond S. Reed, Merchandise Manager, Home Furnishings' Division, John Wanamaker, Phila. Awards for top 28 campaigns, chosen from 300 entries, will be presented to companies and their agencies at a luncheon program in New York's Plaza Hotel on April 26.

Engineering Handbook

De Laval Steam Turbine Co., Trenton, N.J., has published a revised edition of its book entitled "DE LAVAL HANDBOOK" which was compiled by the De Laval Engineering Staff and edited by Austin H. Church and Hans Gartmann. The title page states that the book is an engineering data book for users of pumps, turbines, compressors and gears. The book covers mathematical, mechanical and fluid information of a general nature applying to more than one of the following sections: Steam turbine data; centrifugal pump data; IMO pump data; compressor, blower and exhauster data; helical reduction gear data and worm reduction gear data. Complete with tables, diagrams and photographs the book consisting of over 290 pages is available from the De Laval Steam Turbine Co., at $2.00 per copy.

STOP by ANNISTON and See—
M&H
CHICAGO
CINCINNATI
ST. LOUIS
LOUISVILLE
NASHVILLE
KNOXVILLE
MEMPHIS
CHATTANOOGA
ANNISTON
BIRMINGHAM
ATLANTA
JACKSONVILLE
TAMPA
MIAMI
On your way to or from the Miami A.W.W.A. convention April 29—May 4, we cordially invite you to stop over at Anniston, Alabama, and visit with us. Whether you travel by rail, air or auto, your route from the East, North or Middle West will pass close to our Main Office and Plant which is about half-way between Birmingham and Atlanta, at the junction of U. S. Highways 78 and 241. It will indeed be a pleasure to welcome you and your convention party.
M & H VALVE
AND FITTINGS COMPANY
ANNISTON, ALABAMA
M&H PRODUCTS Everywhere

Excerpts from Purdue's Sanitary Engineering News*

From data accumulated from Green Bay, Wisconsin, on the operation of trickling filters, it appears that a 70% reduction through a 3-foot deep filter can be obtained with a loading of .25 pounds of B.O.D. per square foot. If two stage units are used the loading could be increased to .75 pounds B.O.D. per square foot on the first stage.

The Hoover report showed that the average working citizen must work on an average of 61 days per year to pay his taxes. Check up and see if you are getting your money's worth.

The new total hardness test is a method based on the titration of a water sample with an organic sequestering agent which will form unionized complexes with calcium and magnesium. The titration is performed in the presence of an indicator which is red in the presence of calcium and magnesium ions and blue in their absence.

In the period 1665 to 1668, Sir Isaac Newton evolved and generalized the binomial theorem, laid down the first principles of differential calculus, discovered the laws of gravity, developed the first reflecting telescope, discovered the refractive power of glass prisms, explained the nature of white light and origin of color; that colors of the spectrum are produced by refracted white light passing through a glass prism. I think that is a pretty good three years' work.

From 1936 to 1946, 2,650,000 tons of sediment were deposited in Lake Decatur, Decatur, Illinois, while an estimated 750,000 tons passed over the spillway. This constitutes a loss of 3,400,000 tons of soil from farms of the drainage area *during the 10 years.* Although this is only part of the total soil loss, it is equivalent to complete removal of 7 inches—the plow depth—of fertile topsoil from 3,400 acres of land.

At Clear Lake, California, billions of gnats plague the residents of the

Edited by Prof. Don E. Bloodgood

(Continued on page 126A)

LOOKING FOR IMPROVED COAGULATION ?

FREE INFORMATION ON REQUEST

FROM THE

TENNESSEE CORPORATION
Atlanta, Georgia — Lockland, Ohio

ON FERRI-FLOC, THE NEW FERRIC IRON COAGULANT. FREE 35 PAGE BOOK ON WATER AND SEWAGE TREATMENT WITH...

FERRI-FLOC

(Continued from page 124A)

resort area. Rhothane has been used and it is believed that this substance has eliminated the gnats without damage to other living things in the area.

In Chicago and Los Angeles the wet method for the storage of activated carbon is being used. At Youngstown, Ohio, it was decided to store the activated carbon in the dry state. It is apparent that great care must be used in controlling the temperatures of dry carbon in storage.

The 1949 report from Oshkosh, Wisconsin, says that one of the gas engines at the sewage treatment plant is to be given a complete overhaul after 47,000 hours of operation (some 5½ years).

Indianapolis Pumping Supt. Retires

Mauch completes 43 years plus

After forty-three and a half years of service, T.C.M. (Teddy) Mauch, retired from work at the Indianapolis Water Co. Thirty-seven of those years were spent as Superintendent of the Pumping Department. Mr. Mouch joined the company in 1907 as an engineer of well operation. Then he became an assistant at the Washington Station where he helped the hydraulic turbines; from there he went to the Riverside Station and on March 13, 1913 was named Supt. of the Pumping Dept. Twelve days later the famous flood of March 1913, put the station out of service. The water department was the last utility out of service and after 56 hours was the first back in service.

During Mr. Mauch's tenure of four decades plus, he saw the city grow from 216,000 to nearly 500,000 persons; and the water pumpage grew too—from 18 mgd. to about 55 mgd.

At a farewell party held by his fellow employees, he was presented with a "diploma" from the "University of Water Supply."

Interstate Sanitation Commission Report

The Interstate Sanitation Commission, which represents the states of New York, New Jersey, and Connecticut and is concerned with water pollution in the metropolitan area around New York City, has submitted its annual report for 1950.

The report points out that in 1936, when the Commission was formed, the total amount of adequately treated sewage in the area was only 7,000,000 a day. When sewage treatment plants now under construction are finished, the daily total of treated sewage will be 1,025,000,000 gallons per day.

For the same period, the number of sewage treatment plants has increased from 20 to 116 and the total number of persons being protected from the effects of polluted waterways has increased from 500,000 to 7,350,000. Seth G. Hess is Chief Engineer of the Commission.

Something New Has Been Added

Band Heralds Sewage Plant Opening

When the Warren, R.I. new sewage treatment plant was opened, its dedication ceremonies included a parade by the Warren Indian Band. Also included in the dedication were a few brief speeches by the mayor, the sewer commissioner, the chairman of the pollution abatement committee, and a president of one of the local industries. The ceremony was held at the sludge digester building where the daughter of Oliver Rene, Sewer Commission Secretary unveiled a dedicatory plaque.

Builders Visible Flow Chlorinizers are designed to *simplify* plant operation — not to complicate it. Any competent mechanic with a knowledge of the proper methods of handling chlorine can easily master the operation and maintenance of Builders Chlorinizers. Specially trained personnel are not required to operate or service these chlorine gas feeders. The utmost safety and dependability are assured when Builders Chlorinizers handle your chlorination jobs. For Bulletins and complete information, address Builders-Providence, Inc. (Division of Builders Iron Foundry), 350 Harris Ave., Providence 1, R. I.

BUILDERS PRODUCTS
The Venturi Meter • Propelofio and Orifice Meters • Kennison Nozzles • Venturi Filter Controllers and Gauges • Conveyaflo Meters • Type M and Flo-Watch Instruments • Wheeler Filter Bottoms • Master Controllers • Chlorinizers — Chlorine Gas Feeders • Filter Operating Tables • Pneumatic Meters • Chronaflo Telemeters •

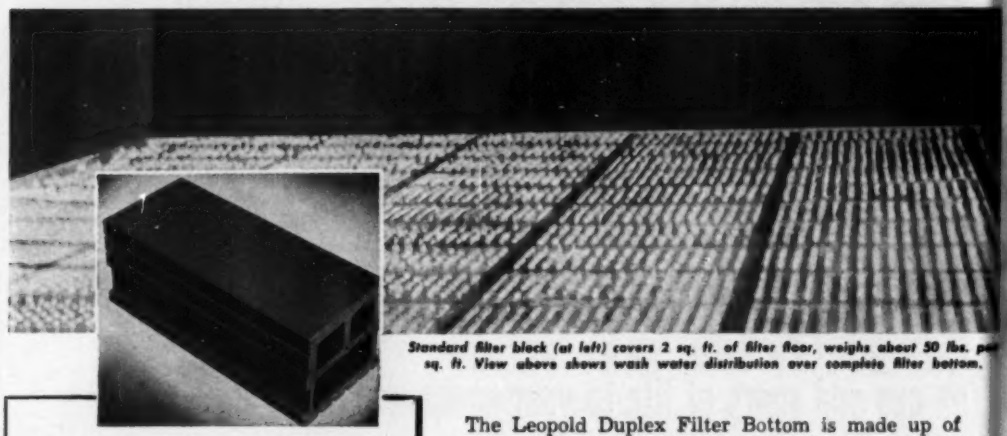
Installation in Sewage Plant, Medina, Pa.

BIF INDUSTRIES — **BUILDERS-PROVIDENCE** — BUILDERS

Proved and Approved in over *200* Purification Plants...

The LEOPOLD *Glazed Fire Clay* TILE FILTER BOTTOM

Permanent • Non-Corrosive • Economical



Standard filter block (at left) covers 2 sq. ft. of filter floor, weighs about 50 lbs. per sq. ft. View above shows wash water distribution over complete filter bottom.

Only the LEOPOLD Filter Bottom offers *all* these features:

1. **No possible corrosion or tuberculation anywhere in the filter bottom.**
2. **De-aired fire clay blocks are practically non-absorbent.**
3. **Equal filtration; also equal distribution of wash water over entire bed.**
4. **Requires only shallow depth of small sized filter gravel.**
5. **Extremely low loss of head.**
6. **Adaptable to any rectangular filter units.**
7. **Long life and highly efficient performance.**

The Leopold Duplex Filter Bottom is made up of individual blocks which are firmly joined together to provide a strong bed that is not disturbed by wash water. With this efficient, enduring system, you're assured an equal collection of filtered water with extremely low loss of head. There is no possible corrosion or tuberculation anywhere in the filter bottom.

Made of de-aired fire clay—vitrified and salt glazed, the highly efficient Leopold Filter Bottom requires only shallow depth of small sized filter gravel and is acid and alkali resistant. Adaptable to any rectangular filter unit, it won't absorb any detrimental amount of water.

Literature and complete details on request!

F. B. LEOPOLD CO., INC.

2413 W. CARSON STREET • PITTSBURGH 4, PA.

WATER PURIFICATION AND SEWAGE PLANT EQUIPMENT

Advertising for Rain

Idea of a Texas Editor

The drought around Kingsville, Texas, was the worst in 33 years. The enterprising editor of the local newspaper said "Why Not?", and went to work to sell Kingsville merchants on collectively advertising for rain in a full-page "Want Ad." Here's what the ad called for—

Wanted—One ground-soaking rain for the entire Bishop area, and all other areas badly in need of rain. Prefer down-pour followed by slow steady drizzle; but, just any kind of rain will be welcome.

Material on Water Pollution Control

The Federal Security Agency, Public Health Service, Division of Water Pollution Control has published a very informative pamphlet — "Guide to Source Material on Water Pollution Control." This pamphlet should be a "must" for all those engaged in, or concerned with the prevention and abatement of water pollution. Covering practically all available information regarding water pollution, the pamphlet lists all the state water pollution control agencies and interstate water pollution control agencies. Films are listed with information regarding size of film, sound or silent, color or black and white, running time and who produced it. Papers, reprints of articles, reports and discussions covering Financing, Economic Factors and Policy, Industrial Wastes, Domestic Wastes, Laws and Regulations, Stream Pollution Investigations, Water Use and Standards, and Public Health Aspects are included giving short explanations of material covered and the source.

All material listed is available for distribution. Write USPHS, Div. of Water Pollution Control, Washington, D.C., for this "Guide to Source Material on Water Pollution Control."

Hill & Hill Move Offices

Hill and Hill, Engineers, North East, Pa., have announced that they have moved from their previous location at 24 East Main Street, which has been owned and occupied by them for 50 years to the first floor at 8 Gibson Street. According to the company the new quarters will provide for additional space and for laboratory facilities for sewage, water works and industrial wastes analysis and investigation.

Egypt to Drink Pure Water

But Oldsters Rebel for Interesting Reasons

Under a five year plan at a cost of approximately $50,000,000 the government of Egypt is to construct water purification plants so that Egyptians may have pure, clear water to drink.

The peasant classes have, interestingly, objected to clean, clear water in the past on the grounds that clear and colorless water lacks the sustenance contained in the muddy Nile water and that from irrigation ditches. They claim that the Nile water has "body" to it, which clear and colorless water is "unhealthy and the cause of impotence."

Nat. Tech. Task Comm. on Ind. Wastes Reports Progress

Various branches of industries in the United States are making definite progress toward more effective control of wastes which contribute to the pollution of the nation's waterways, it was reported to the National Technical Task Committee on Industrial Wastes at its meeting in Cincinnati.

Upon its organization in May 1950, the Committee agreed on these

(*Continued on page* 130A)

You can add years of life to your equipment with PITT CHEM Protective Coatings

In these busy days . . . when new equipment is hard to get . . . you'll want to make your *present* equipment *last* as long as possible—*produce* as much as possible. That's where Pitt Chem Protective Coatings fit into your picture. They guard equipment with a tough, impervious film that protects surfaces against practically all types of industrial corrosion and contamination.

Laboratory-controlled from raw materials to finished product, Pitt Chem Protective Coatings are completely uniform and dependable. • For more information, write today for new booklet, "Control Corrosion Through Pitt Chem Protective Coatings."

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PITT CHEM
Industry's Most Comprehensive Family of Protective Coatings

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THE SILENT WATCHMAN

DIXIE TANK AND BRIDGE CO.

3523 LAMAR AVE. P. O. BOX 14
MEMPHIS 1, TENNESSEE

Complete Service for Elevated Water Tanks—
Nation Wide Service—30 Years Experience

KEEP THE SAFETY FACTOR IN
YOUR TANK THE DIXIE WAY

By welding seams, pits and rivets which gives a riveted tank 15% more Safety Factor than it had when built. No rivets removed, water supply maintained while work is in progress. On completely reconditioned jobs, the painting is guaranteed for five years, repairs guaranteed for ten years, provided the tank is painted every five years by Dixie Tank and Bridge Company. Yearly inspection, making all adjustments, if any, without additional cost.

Write Us for Free Copy of Publication

SOUND PRINCIPLES OF WATER TANK MAINTENANCE and TANK TALK, by W. A. RILEY

—SAFETY—SERVICE—SATISFACTION—

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THE LARGEST ORGANIZATION OF ITS KIND GIVING SAFE MAINTENANCE AT LOW COST

(Continued from page 128A)

initial tasks. (1) assemble a list showing sources of information on processes and practices known for using, treating and controlling industrial wastes; (2) assemble a tabulation of research projects concerned with utilization, treatment and disposal of wastes, those underway and those contemplated; (3) provide a list which will define problems that confront a given industrial group and for which there is no satisfactory solution, particularly those which are common to more than one industry. The task groups established covered food, mineral products, chemical processing and general industries.

Special reports were made to the Committee at the Cincinnati meeting covering the four industrial task groups. Speaking for the food industries, Frank McKee, kraft Food Company, Chicago, said that his Task Group recommended further studies to determine the self-purification capacities of streams to evaluate the maximum economic usage of stream resources. The group also recommended to the Water Pollution Control Advisory Board that the Board draft and recommend adoption of a law granting five-year amortization of industrial waste treatment facilities.

The report for the task group covering mineral products industries was given by L. C. Burroughs, Shell Oil Company, New York, who covered the coal, coke, iron, steel and petroleum industries. In practically every anthracite mine operation where cleaning plants have been installed, large sedimentation and clarification equipment has been put in use. Acid mine water drainage continues to be a serious problem, Mr. Burroughs reported, but research is being continued at several locations to solve it.

"One of the most difficult problems of the By-Products Coke Industry is the disposal of waters containing phenols, cyanides and oily wastes."

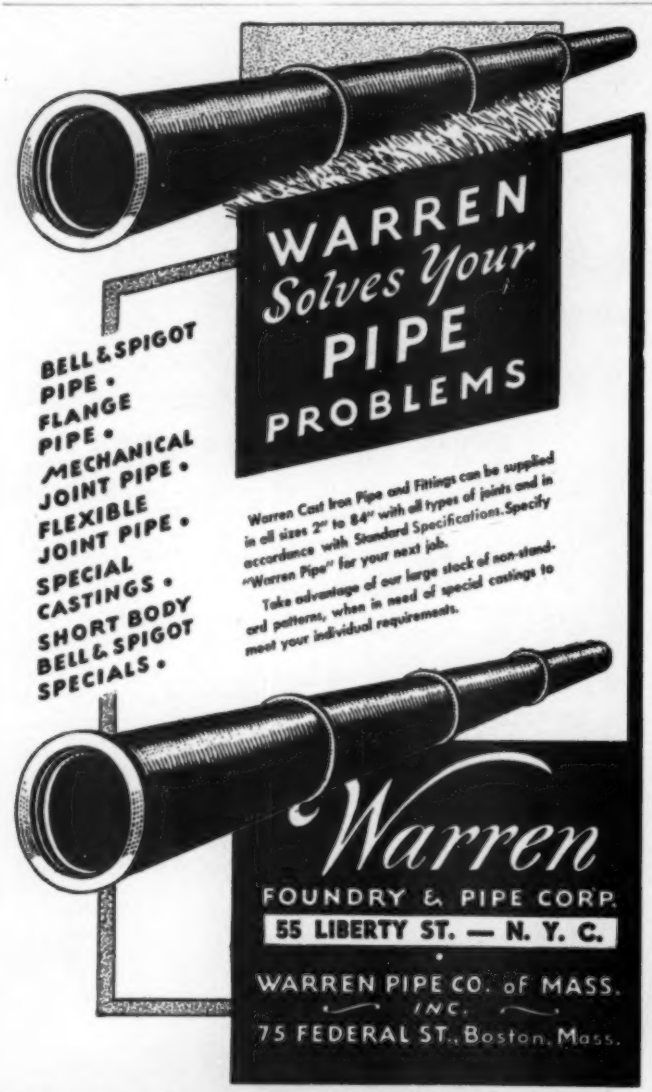
The American Wire and Steel Institute is continuing research to investigate processes proposed for treating steel mill wastes, and research toward development of new treatment methods. "Major attention is being given to pickle liquor disposal, but to date no universally applicable process has been evolved."

"Cooperative waste disposal work in the oil industry is concentrated largely in the American Petroleum Institute's Committee on Disposal of Refinery Wastes which, at the present time, has under way a heavier program of work than at any time in its 22 years of existence," Mr. Burroughs said. He added that the Institute hopes to publish later this year, new and greatly expanded editions of the manuals on (1) sampling and analytical testings of waste waters and (2) methods and devices for disposal of chemical wastes.

Dr Harry Gehm, Technical Director, National Council on Stream Improvement for the Pulp, Paper and Paperboard Industries, New York, reported for the task group covering the chemical processing industries. This task group recommended that the Environmental Health Center of the Public Health Service at Cincinnati make fundamental studies on problems common to the industries of this group, such as the thickening and dewatering of hydrous residues obtained in treatment of some wastes.

L. A. Danse, Supervisor, Production Engineering Section, General Motors Corporation, made a brief report for the task group covering general industries, including automotive, electrical equipment, lumber, railroads, and other industries as represented by the National Association of Manufacturers.

(Continued on page 132A)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PIPE
PROBLEMS
BELL & SPIGOT PIPE • FLANGE PIPE • MECHANICAL JOINT PIPE • FLEXIBLE JOINT PIPE • SPECIAL CASTINGS • SHORT BODY BELL & SPIGOT SPECIALS •
Warren Cast Iron Pipe and Fittings can be supplied in all sizes 2" to 84" with all types of joints and in accordance with Standard Specifications. Specify "Warren Pipe" for your next job.
Take advantage of our large stock of standard patterns, when in need of special castings to meet your individual requirements.
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EXPANDING ROOT CUTTER AND SEWER CLEANER

Open and in action

removing roots and caked sediment like this.

It Fits in on Every Sewer Cleaning Job
SURE GRIP SEWER RODS
and ACCESSORIES

are joined together with a dual lock forming a rigid chain.

Write for our new catalog on complete sewer cleaning equipment.

EXPANDING SEWER MACHINE COMPANY
108 EAST WALNUT ST. NAPPANEE, IND.

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FLOORING
WALKWAYS
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DRAIN GRATES
In
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Specify
IRVING
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and get
CLEAN
DRY
SAFE
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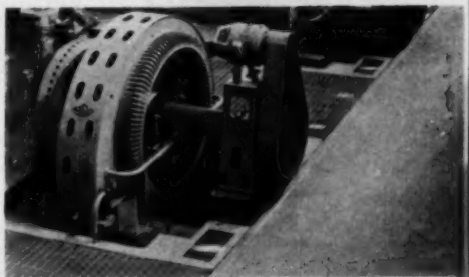

IRVING ALUMINUM GRATING-FLOORING BETWEEN MACHINES IN POWER AND BLOWER BUILDING OF SEWERAGE DISPOSAL PLANT

IRVING SUBWAY GRATING CO., INC.
ESTABLISHED 1902
5089 27 ST., LONG ISLAND CITY 1, N. Y.
1889 10 ST., OAKLAND 20, CAL.
REPRESENTATIVES IN PRINCIPAL CITIES LISTED IN PHONE BOOK UNDER IRVING SUBWAY GRATING. LICENSEES IN CANADA AND MEXICO

What Does Sludge Incineration Cost?

Year	Tons Incinerated		Total Cost Operation & Maintenance	
	Dry Solids	Wet Cake	Per Ton Dry Solids	Per Ton Wet Cake*
1940	37,091	116,000	$1.36	$.436
1941	35,993	112,000	1.23	.394
1942	33,838	106,000	1.17	.375
1943	32,955	103,000	1.39	.445
1944	33,758	105,500	1.27	.407
1945	32,428	101,000	1.38	.442
1946	33,581	105,000	1.54	.493
1947	36,633	114,000	1.42	.455
1948	34,549	108,000	1.79	.573
1949	34,787	108,500	1.73	.554
Average	34,56.13	107,900	$1.43	$.457

*Based on average of 68% moisture in filter cake

The figures above were taken from Annual Reports of Minneapolis-St. Paul Sanitary District, 1940-1949. Nichols Multiple Hearth Mechanically Rabbled Furnaces are employed.

Nichols Multiple Hearth Incineration Shows Low Ten Year Average Cost.

1. Dependable LOW Cost operation.
2. Over 100,000 tons of cake disposal each year.
3. Only 0.2 gals. of fuel oil consumed per ton of cake produced.
4. Individual furnace units operated continuously throughout the year without shutdowns for repairs.

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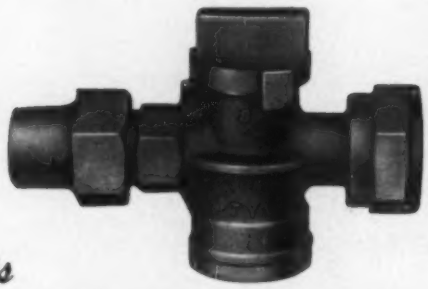
Mid-Western Office: 1920 N. Meridan St., Indianapolis 2, Ind.
Canadian Office: 1477 Sherbrooke St. W., Montreal 25

(*Continued from page* 130A)

Progress made in extending Committee membership to include representation of cane sugar, ceramic, fisheries, frozen foods, lumber, paint, varnish and lacquers, railroads, textile and power production industries, was reported by Committee Secretary Louis F. Warrick, Chief, Technical Services Branch, Division of Water Pollution Control, U. S. Public Health Service. He said that representation on the Committee was being expanded to secure adequate coverage of the industries having industrial waste disposal problems.

The Nat. Tech. Task Comm. on Ind. Wastes adopted as a regular policy the task of collecting basic information on waste treatment and pollution abatement measures, and the dissemination of this information to public or private agencies concerned with the subject matter. The policy of the Committee with respect to recommendations for Congressional appropriation for water pollution control work will be to confine such recommendations to the needs for basic research in the broad public interest, it was decided. The Committee will not concern itself with the need for appropriations to provide loans or grants to municipalities for preparation of plans or construction of treatment works, it was agreed. Under its general policy, the Committee agreed to provide periodical releases of information about its activities and meetings. Membership on the Committee, it was decided, is to be confined to industries having more or less direct concern with waste utilization and treatment problems in effecting stream improvement.



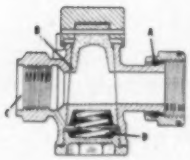
This

METER VALVE

Saves installation costs where space is limited

Permitting "in-line" setting of meters in tight space, the Ford Straight Ringstyle Valve also saves fitting labor and at least one coupling.

This valve enjoys all of the advantages of the famous Ford Angle Ringstyle valve. Note these features: (A) Ringstyle coupling that eliminates a pipe joint as well as a coupling (B) Recessed key that keeps deposits from damaging valve surfaces (C) "Set-in" threads to protect threads of iron pipe and (D) Bronze spring that keeps key in place. No leather gasket required, prolonging valve life.



For full information, ask for Catalog that also contains details on many other meter-setting products for economy minded utilities.

THE FORD METER BOX COMPANY, INC.

FOR BETTER WATER SERVICES

FORD

Wabash, Indiana

The Water-Clock of Athens

St. Paul Told Time by It in Year 51 AD.

The *Christian Science Monitor* tells of the visit to Athens by the erudite apostle St. Paul of Tarsus in the year 51A.D., and of the novel Water-Clock of this day which was located in the main square of Athens. In this central place of commerce and civic activities stood the famed Water Clock of Athens. It was located in an eight-sided marble tower bearing several sundials. On the inside of the tower was the mechanism of the water-clock which measured the passing of time by measuring the quantity of water which had passed through a small orifice as it passed from one vessel to another.

This may not have been the earliest device for the telling of time when sundials were of no value, but it certainly was amongst the earliest; and, too, it originated in the country of the inventor of the water-screw and other devices involving applied hydrostatics —the famed Archimides.

Industrial Chemistry

Reinhold Publishing Corp., New York, N.Y., has published the new fifth revised edition of "INDUSTRIAL CHEMISTRY" by Emil Raymond Reigel. It contains over a thousand pages of text and illustrations and covers the plants, equipment, machinery, materials and processes in over fifty chemical and process industries.

New material not represented in the previous edition included antibiotics, the new organic insecticides and fungicides, the utilization of wood, novel methods of the application of dyes to fiber, atomic energy, and recent developments in plastics and petroleum. The chapter on water purification and sewage treatment was prepared in collaboration with Dr. George E. Symons, Man. Ed., *Water & Sewage Works*.

The book may be obtained from Reinhold Publishing Corp. for $7.00 per copy.

Manufacturers' and Equipment News

Anti-Rust Paint

401

Speco, Inc., Cleveland, Ohio, has announced the addition of three new specially chromated anti-rust paints to its RUSTREM (Rust Remedy) line of maintenance coatings.

Known as Rustrem Chromate Special, the new paints are available in clear, black and aluminum. This special paint was produced to meet widespread requirements for an extra effective anti-rust paint, and according to the manufacturer it is reputed to stand up longer under extreme conditions of temperature and moisture than any previously available anti-rust paint.

Like standard Rustrem, the chromated product can be applied right over rust without wire brushing or scraping, no primer is required and it is suitable for both interior and exterior use.

Atlas Mineral Appoints Deakin

Atlas Mineral Products Co., Mertztown, Penna., has announced the appointment of Donald F. Deakin as Product Director in charge of Water and Sewer Materials. Mr. George L. Wirtz, president of Atlas, stated that this appointment was in keeping with the plant expansion program of the company. Mr. Deakin is a graduate of Penn State with a degree in civil engineering.

Electronic Feedwater Control

402

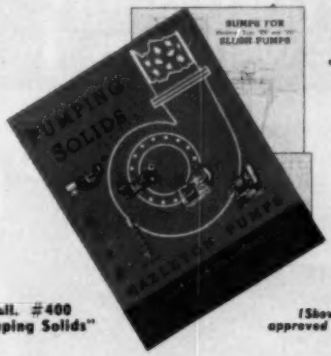
Lumenite Electronic Co., Chicago, Ill., has announced the development of an electronic boiler feedwater and firing control that maintains a constant level of water. According to the company, the control maintains an exact level of water regardless of pressure or temperature and should the water supply fail, it cuts off the fuel supply and activates an alarm.

IF . . .

PUMPING INDUSTRIAL WASTES

IS YOUR HEADACHE—

SEND FOR THESE BULLETINS!



Bull. #419 "Sumps for 'VS' Pumps"

Bull. #400 "Pumping Solids"

(Shows Penna. approved construction)

THE MOST VERSATILE LINE OF HORIZONTAL & VERTICAL PUMPS AVAILABLE . . . .

BARRETT, HAENTJENS & CO.

HAZLETON, PA.

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Huntington, W. Va. Phoenix, Arizona

If interested in equipment or literature mentioned above, mail a Reader Service Card with your name, address, and item key number.

"GUNITE" ENLARGES AND IMPROVES RESERVOIR

In 1947 we "GUNITED" the West End Reservoir at Hagerstown, Maryand. The pictures clearly show important stages in our work to give it greater capacity and to stop excessive leakage. After existing cracks in the concrete floor were sealed, "GUNITE" was applied to waterproof and reinforce the stone masonry and to add 30 inches to the height of the walls.

Many instances of repair, remodeling and new construction with "GUNITE" are described and pictured in Bulletin C2400. A request on your letterhead will bring your free copy by return mail.

CEMENT GUN COMPANY
"GUNITE" CONTRACTORS
GENERAL OFFICES—ALLENTOWN, PENNA. U.S.A.
MANUFACTURERS OF THE CEMENT GUN

This outstanding result is produced with N-Sol (Activated Silica) as coagulating aid. Paper mill wastes are clarified so they can be re-used or discharged directly into streams. In addition, recovery of fiber, filler and other chemicals saves money.

N-Sol (Activated Silica) is economical to use . . . prepared in the mill from N® Silicate of Soda and a reactant such as chlorine, alum, ammonium sulfate, sodium bicarbonate. Samples of "N" and directions for jar tests for raw water and wastes on request.

PHILADELPHIA QUARTZ COMPANY
Manufacturers of Soluble Silicates
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N-SOL PROCESSES FOR WATER COAGULATION

The Model FB control is supplied as a complete unit, ready for installation to operate solenoid valves, motor starters and alarms. Attached to the boiler—along side of the conventional water-level glass—is the heavy navy bronze housing for the three electrodes. This housing is tested and guaranteed for 200 lb. pressure. Controls come set for a ½ inch variation in the level of the water but can be set closer or wider if desired.

Edwin R. Bartlett
Board Chairman.

R. Lindley Murray
New President.

Executive Promotions At Hooker

Hooker Electrochemical Co., Niagara Falls, New York, at a Board of Directors meeting elected Mr. Edwin R. Bartlett to the Chairmanship of the Board. R. Lindley Murray was at the same time promoted to the office of President of the company.

Mr. Bartlett has been associated with the Hooker Company since 1907 in various capacities, having been made a vice-president and director in 1924. He has been President of the firm since 1945. He is an officer of several other companies, being both President and a director of Hooker-Detrex, Inc. a subsidiary.

Mr. Murray has been with Hooker since 1916. He has been a director since 1937 and is a vice-president and director of Hooker Dextrex.

Worthington-Gamon Now Division of Worthington

Worthington-Gamon Meter Co., Newark, N.J.—formerly a subsidiary of Worthington Pump and Machinery Corp.—has been made a division of that corporation.

The new division will continue the manufacture of liquid meters at the former company's Newark plant, according to H. C. Ramsey, President. Robert R. Anderson, formerly president, Worthington-Gamon Meter Co., has been elected vice-president of Worthington Pump and Machinery Corp., and will act as general manager of the new division.

William C. Flanders, formerly vice-president of the meter company, has

If interested in equipment or literature mentioned above, mail a Reader Service Card with your name, address, and item key number.

been appointed assistant general manager of the Division and Walter H. Zeis, formerly secretary and treasurer of the meter company, has been elected assistant secretary of the Worthington Corporation.

Recorder for Rotor Temperature

403

Minneapolis-Honeywell Regulator Co., Brown Instrument Div., Philadelphia, Pa., has developed an electronic recorder for accurately and quickly measuring temperature of the rotor in large electric generators.

The ElectroniK has been designed to provide a better and more economical instrument to assist operators in avoiding overloads. In addition, the instrument furnishes a 12-inch strip chart record which can be used as a guide for gradually cooling a generator.

R. W. Lindsey Joins Builders and Omega

Builders-Providence and Omega Machine Co., Providence, R.I., have announced that Ray W. Lindsey has joined the engineering sales staff in the Wilmette, Illinois office.

Mr. Lindsey, who is a graduate Civil Engineer from the University of Minnesota, has previously been associated with the consulting engineering firm of Hitchcock and Estabrook in Minneapolis, Minn., from August 1946 to November 1950. Prior to that Lindsey spent two and one-half years in the Navy.

A member of ASCE and American Society Naval Engineers, Ray Lindsey will cover the territory out of Chicago and Wilmette for both companies.

Worthington Acquires Wintroath Pumps

Worthington Pump and Machinery Corp., Harrison, New Jersey, has acquired Wintroath Pumps Inc., of Alhambra, Calif. According to H. C. Ramsey, President of Worthington, the Wintroath Co. will operate as a wholly owned subsidiary of Worthington, continuing under present management with Boyd Kern re-

CHECK LEAKAGE with Simplex Waste-Water Detection Equipment

Breaks in pipe lines or leaking joints have always been an annoying problem to municipal engineers. Not only money but precious water is wasted. That's why it pays to detect the leaks in your water system . . . and there's no easier way to do it than with Simplex portable equipment!

The combination of Simplex pitot rod, manometer and recorder is ideal for checking water wastes and measurement of flow through pipe lines in hard-to-get-at places or where permanent measuring equipment is not installed. Each unit is light in weight and ruggedly designed to withstand the hard treatment of being moved from station to station.

For free Bulletin #50, write to Simplex Valve and Meter Company, Dept. 4, 6743 Upland Street, Philadelphia 42, Pa.

SIMPLEX

VALVE AND METER COMPANY

FREE

to WATER WORKS and SEWAGE MEN

HOW TO CONTROL ALGAE

"The Use of Copper Sulphate in Control of Microscopic Organisms" by Dr. Frank E. Hale (former Director of Laboratories, Dept. of Water Supply, City of New York) is an authoritative work concerning the control of micro-organisms and elimination of tastes and odors. Describes in detail methods of controlling various forms of microscopic life commonly encountered in water supply systems. Contains descriptive material, plus 48 photo-micrograph studies of organisms discussed.

ROOT AND FUNGUS CONTROL

"Copper Sulphate for Root and Fungus Control in Sanitary Sewers and Storm Drains," by John W. Hood, contains information published for the first time. This material includes actual methods for control and operating procedure. Here's the book that is a "must" for all sewage men.

GET EITHER OR BOTH OF THESE BOOKLETS ABSOLUTELY FREE— These two valuable booklets, so important to all water works and sewage men, are yours *without obligation.* Mail coupon below!

Write Today, Supply Limited!

PHELPS DODGE REFINING CORPORATION
40 Wall Street, New York 5, N. Y.

Please send my free copy of (check one or both):

☐ "Control of Microscopic Organisms"
☐ "Copper Sulphate for Root and Fungus Control in Sanitary Sewers and Storm Drains"

Name _____ Title _____

Employed by _____

Address _____

City _____ Zone _____ State _____

WS-451

maining as president. Organized in 1929, Wintroath has become one of the leading manufacturers of vertical turbine well pumps.

By expanding operations at Alhambra, Ramsey said his company will be enabled to better serve the evergrowing markets in the western states.

Mark Owen Now Vice Pres. Nichols Engineering

Mark Owen, for the past several years a consulting engineer in Indianapolis, Ind., is returning to the Nichols Engineering and Research Co., as Vice Pres. In his new position, Mr. Owen will be in charge of a new branch office which is being opened in Indianapolis.

Prior to entering the consulting field, Mr. Owen was associated with the Nichols Co. in New York City. Prior thereto, he was City Engineer of Dearborn, Mich., and in 1936 served as president of the American Public Works Association.

Jack O'Leary Elected President of Constructors

John E. ("Jack") O'Leary, vice-president and general sales manager of Pittsburgh Des Moines Steel Co., Pittsburgh, Pa., has been elected to the presidency of the Constructors Association.

Mr. O'Leary has served the Association as a member of the Board, Chairman of its Public Relations Committee and vice-president. His successor as vice-president is Howard H. Sturdy vice-president of Dravo Corporation.

Worthington Buys National Transit Pump

Worthington Pump & Machinery Corp. has announced the purchase of the plant and equipment of National Transit Pump and Machine Corp. of Oil City, Pa.

Miscellaneous overflow from Worthington's other factories will be diverted to the new plant, according to Austin C. Ross, vice president in charge of Worthington's Buffalo

DEPENDABLE Marlow Pumps... *preferred from coast to coast!*

PLUNGER SLUDGE PUMPS

Bulky debris and nearly solid sewage wastes are routine for these rugged, trouble-free units. In four sizes and two types. Any capacity required.

SELF-PRIMING CENTRIFUGALS

Prime automatically, virtually clog-proof. You can rely on these able pumps for low-cost, low maintenance service with clear or semi-clear fluids. From small portables to units of 240,000 GPH capacity.

MARLOW MUD HOGS

The diaphragm pump that can't be beat for handling mud-filled or trash-laden liquids. Extra heavy construction. Capacities to 9000 GPH. Ask especially for details of the new lightweight Mud Hogs.

For complete details see your Marlow distributor or write the factory.

MARLOW PUMPS
243 GREENWOOD AVENUE
RIDGEWOOD, NEW JERSEY
THE STANDARD OF THE INDUSTRY

If interested in equipment or literature mentioned above, mail a Reader Service Card with your name, address, and item key number.

plant, who will also have administrative charge of the new operation.

The former Transit plant covers 500,000 square feet, includes iron, steel, and brass foundry, pattern shop and forge shop, machine shops and assembly floor, test facilities, power house, steel fabricating shop and administration building.

Worthington plans to continue to furnish repair and spare parts for the products of National Transit Pump and Machinery Co., now in the field.

Submersible Pump

404

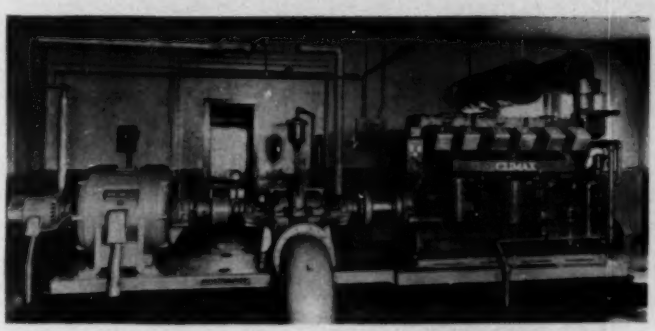
Fairbanks, Morse & Co., Chicago, Ill., has announced the development of a new submersible pump. According to the company, this new pump has many features: it is a self-priming deep well pump installed below the water level; it is easy to install (simply add pipe lengths to reach the water). No jets, rods or shafts are required. It is water-cooled, water-lubricated and self-priming.

It is designed to deliver unusually high capacities at settings in excess of 70 feet with well diameters of 4 inches and larger. The motor and pump are assembled in a tubular frame and the motor embodies a sealed rotor and stator, which is water-lubricated and water-cooled. The motor relay and capacitor are located in a control box above ground where they are easily accessible, and may be removed without disturbing the main well installation.

Rockwell Names Dixon

Rockwell Manufacturing Co., Pittsburgh, Pa., elected L. A. Dixon a Director of the Company at a recent board meeting. He has been a Vice

climax DEPENDABILITY



Climax Blue Streak 12 cylinder engine as standby for 5500 G.P.M. High Head Service Pump at Michigan City Water Works.

More Municipalities are Selecting Climax Engines Because of Their...

FLEXIBILITY
QUICK STARTING
LOW COST MAINTENANCE

In municipal water works plants Climax Blue Streak Engines drive generators and pumps in standby service, or furnish continuous power where natural or by-product gas is available.

Climax Engines are recommended for direct connection to individual pumps or through disconnect, free wheeling or automatic clutch couplings to motor driven pumps, where the motor is used for normal operation and the engine for emergencies.

For water works service Climax Engines are the choice because of their low upkeep expense, extra quick starting and sufficient surplus capacity to supply power for an indefinite period of time.

Service records show many installations have rendered reliable service for over 15 years.

Write for complete information and specifications on these dependable power plants. There are 4, 6, 8 and 12 cylinder engines, rated from 40 to 600 HP, operating on natural gas, Butane or gasoline. Sewage gas engines are *available* in sizes 40 to 250 HP.

climax ENGINE AND PUMP MFG. CO.

Factory and General Office
Clinton, Iowa

Regional Offices
Chicago - Dallas - Long Beach, Cal.

EJECT-O-MATIC Model TE SEWAGE EJECTOR

for continuous, trouble-free economy in handling of sewage lift problems

For day-in-and-day-out 100% sewage boosting you can't afford *not* to consider Carter's pneumatic sewage ejectors. They practically pay for themselves by elimination of the costly auxiliary screening equipment required with centrifugal pumps. Solids and trash up to the size of the inlet and discharge valves are easily handled. No moving parts — no clogging or binding. Pots are either copper bearing, electrically-welded steel or cast iron—to your specifications. Hermatically sealed —completely eliminate stuffing box leaks and toxic gas dangers. Bronze mounted double disc gates and swing check valves. Rotary type air compressors of high volumatric efficiency. Fully automatic controls.

Capacities—30 to 300 GPM

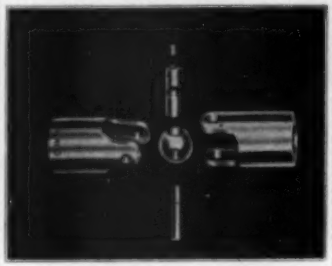
Write Dept. S—give your specific waste problems, and we'll promptly furnish a detailed reply.

186 Atlantic St., Hackensack, N. J.

R. B. CARTER SALES INC.
Hackensack, New Jersey

President of Rockwell's Meter and Valve Division since early 1948, and before that was president of the Pittsburgh-DuBois Co., manufacturers of tin gas meters, which is now a division of the Rockwell Firm.

Mr. Dixon is well known in the utility, petroleum and municipal markets, having done considerable field work in the promotion of the Company's products for the last twenty years.



Universal Joints

405

Curtis Universal Joint Co., Inc., Springfield, Mass., has announced the development and availability of a new "Lo Friction" Universal Joint. This joint is available in single or double joint form, in sizes of 1¼ inch O.D. or larger, and solid or bored hubs, round, keyed or splined shafts.

According to the company, the secret of the effectiveness of this new joint is to be found in the friction block of the joint—by reducing bearing surfaces and providing for adequate and constant lubrication thru the use of a patented oiler, Curtis has been able to develop this heat resistant joint.

Rockwell Buys Pittsburgh Valve

Rockwell Manufacturing Co., Pittsburgh, Pa., has acquired both the Pittsburgh Valve and Fittings Div. of the Pitcairn Corp., and the Pittsburgh Valve and Fittings Corp., a subsidiary of the Pitcairn Corp., according to W. F. Rockwell, Jr., President.

Manufacturing facilities and principal offices of Pittsburgh Valve are located in Barberton, Ohio. Company-owned warehouses were also acquired in Kansas City and Houston. Leased warehouses are maintained in Chicago and New York. Plant facilities include a completely modern and mechanized foundry for the manufacture of valve castings.

The Barberton operations will be expanded to employ 2,000 people; the plant will be operated as one of Rockwell's meter and valve divisions under the direction of L. A. Dixon, V.P.

BOND-O Homogenized

UNIFORMITY

brings you the perfect jointing compound

Every ounce, every pound, every bag of BOND-O is identical in structure. Every cast iron pipe joint made with BOND-O —if made the same way—will perform in the same way. In short—if made with reasonable care—every BOND-O joint will be a perfect joint.

To the Water Works Engineer, the use of machine blended BOND-O means uniformity in strength — in tightness — in bonding — in initial seepage — in sealing. It means economy through the elimination of faulty joints . . . economy in man hours — and in money. It means that once a BOND-O joint is made, not another cent need be spent on it for maintenance. ***Proof of this is the fact that there has never been a single reported failure of a BOND-O joint!***

BOND-O

NORTHROP & COMPANY, INC.
SPRING VALLEY NEW YORK

If interested in equipment or literature mentioned above, mail a Reader Service Card with your name, address, and item key number.

Owens President of Roots-Connersville

Roots-Connersville Blower Corp., Connersville, Ind., has announced the election of Robert H. Owens as president and general manager, succeeding John Avery who died unexpectedly on January 13.

Mr. Owens, a graduate of Purdue University, came to Connersville in 1925 to join the engineering staff of the P.H. & F.M. Roots Co., a predecessor of Roots-Connersville. With a variety of industrial experience, Mr. Owens was actively connected with the development of the centrifugal line of blowers built by R-C, and has had many years of experience in building blowers.

Jointing Compound

406

Atlas Mineral Products Co., Mertztown,, Pa., after two years of intensive research and testing, has announced the introduction of G-K 58 pipe jointing compound. The new plastic compound is said to be a root resistant hot melt type, having superior adhesion to both wet and dry vitrified clay pipe.

Seaver Jones Retires From Presidency of Centraline

Succeeded by James P. Cummins

H. Seaver Jones, who has been associated with the development of the Centriline Process almost from its inception twenty years ago, has retired as President and Director of the Centriline Corporation. The Centriline Corporation of 140 Cedar Street, New York 6, N. Y., was formed in 1939 to take over the process of cement lining water pipe in place, invented by A. G. Perkins and developed by the T. A. Gillespie Company. Under Mr. Jones' administration, marked progress has been made in developing the application of cement lining for pipes from 4" to 144" in diameter. Mr. Jones will continue to act as a consultant to Centriline.

James P. Cummins has succeeded Mr. Jones as President. Mr. Cummins was formerly East Coast General Superintendent of the Raymond Concrete Pile Co.

U.S. Pipe Acquires Pontusco Corp.

United States Pipe & Foundry Co., Burlington, N.J., has announced acquisition of complete ownership of Pontusco Corp. Pontusco Corp. formerly was jointly owned by the

It's a quick, one-man job to repair a KENNEDY SAFETOP

Photos taken at N. Y. State Section meeting, A.W.W.A., April 1949

IN ONLY 11 MINUTES, a single man can easily and permanently repair a Kennedy *Safetop* sheared off in a traffic accident. It is the only hydrant with the easily-replaceable, threaded breaking ring that gives positive connection and rigid alignment to the two standpipe sections.

HIT BY A SMASHING IMPACT, the *Safetop* breaks cleanly and evenly at the breaking ring. Yet this ring gives a connection strong enough to take as hard a blow as the one-piece hydrant can . . . without damage.

ONLY A FEW COMMON TOOLS and inexpensive parts, contained in the *Safetop* Repair Kit, are needed for permanent repair. No digging is required and a compression-type valve prevents flooding or gushing.

BACK IN SERVICE after speedy, right-on-the-spot repairs, the Kennedy *Safetop* works as smoothly and efficiently as if nothing had happened. There's no danger of prolonged loss of community fire protection.

THE COMPLETE KENNEDY LINE

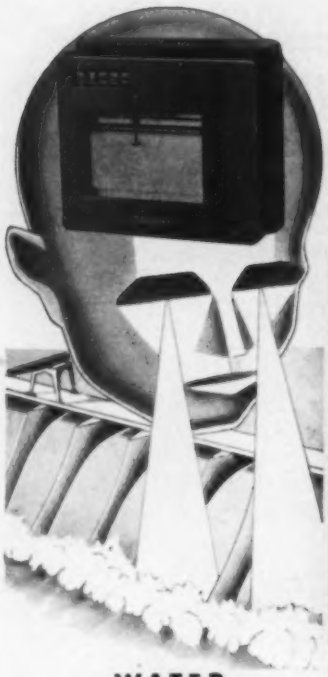
includes a wide range of A.W.W.A. valves and fire hydrants. When you standardize your community on KENNEDY, you are assured of the same high quality and dependability that have characterized all KENNEDY products for 74 years.

WRITE FOR SAFETOP BULLETIN 105

THE **KENNEDY**
VALVE MFG. CO. • ELMIRA, N.Y.

Est. 1877

VALVES • PIPE FITTINGS • FIRE HYDRANTS



WATER
MEASUREMENT
OR CONTROL

STEVENS

GRAPHIC, VISUAL OR
AUDIBLE REGISTRATION

Whether you need a simple staff gage, float gage or complex remote operated recorder, there is a STEVENS instrument to meet your requirements. Water level or flow recorders for weekly service or long periods of unattended operation, direct float operated or remotely controlled; indicators, controls for alarms and pumps . . . the STEVENS line is complete in the field of water measurement and control. We also welcome inquiries concerning special problems.

Pioneers in the field of water level recording for more than 43 years, LEUPOLD AND STEVENS INSTRUMENTS, INC., have developed and perfected precision water measuring instruments of all types to meet a variety of specific needs, especially for water works, sewerage, irrigation and industrial uses.

Write for literature and information on accurate and dependable STEVENS water measuring instruments.

LEUPOLD AND STEVENS INSTRUMENTS, INC.
PORTLAND 13, ORE., U. S. A.

United States Pipe & Foundry Co. and Compagnie de Pont-a-Musson of Nancy, France.

Pontusco Corp. is owner of all the common stock of the United Concrete Pipe Corp., of Calif., which is an important supplier of concrete pipe in California and other western states.

Acid Pouring Device

407

General Scientific Equipment Co., Philadelphia, Pa., have made available the new GS No. 11 Carboy Tilter with pouring spout which assures a safer, faster and easier method of pouring acids and other liquids from carboys. The tilter is constructed with steel supporting members welded and riveted together. The Air Vent pouring spout offers a smooth flow of acid without spurts or splashes. Made of acid resistant rubber and plastic tubing for extra longer life, the spout has a flow capacity of five gallons per minute.

F&P Instrument Course

Fischer & Porter Co., Hatboro, Pa., held an instrumentation course at the Hatboro, Pa., plant from January 15 through 19, 1951.

The course covered manufacture, calibration, installation, operation and maintenance of primary and secondary process control instruments. Users of the company's line of Flowrator instruments found the course particularly valuable.

Pennsalt Moves District Office

Pennsylvania Salt Manufacturing Co., Philadelphia, Pa., has announced that the district sales office of Apple-

Only Taylor Comparators Provide
PERMANENTLY GUARANTEED COLOR STANDARDS
for testing pH and CHLORINE

There's the Value!

There's no danger of mechanical inaccuracy when you use a Taylor Comparator for determining pH or chlorine content of water, sewage or industrial wastes . . . *because all Taylor liquid color standards carry an unlimited guarantee against fading.*

One sturdy plastic slide houses all color standards necessary for any one determination . . . and you need only one base for any number of slides. Each set is complete with slide, base and accessories. They're accurate, easy to operate, sturdy. And the cost is low!

SEE YOUR DEALER FOR SETS. Also ask about complete Water Analyzer.

Write direct for your free copy of "Modern pH and Chlorine Control." Describes and illustrates Taylor Sets, gives theory and practice of modern water treatment.

W. A. TAYLOR AND CO.
7308 YORK RD • BALTIMORE-4 MD

New Shock-Proof Curb Service and Valve Boxes

NEW FEATURE—the SHOCK-PROOF JOINT permits easy, accurate, hand-adjustment. Absorbs surface and road shocks. Asbestos cement pipe with cast iron top and cover. Lightweight, easily installed, corrosion proof. Available in range of standard sizes and styles. Write for detailed information.

DEALERS WANTED

VERAKO PRODUCTS, INC.
Grand Ave. & Skokie Rd.
P.O. Box 604 Waukegan, Ill.

WATERWORKS & SEWERAGE SUPPLIES
Wholesalers and distributors of fire hydrants, valves, cast iron fittings, water meters, copper tube, brass goods, repair sleeves and service saddles, lead, jute, etc.

If interested in equipment or literature mentioned above, mail a Reader Service Card with your name, address, and item key number.

ton, Wis., formerly located at 200 East College Avenue, has been moved to the Irving Zuelke Building in Appleton.

This office, under the direction of C. Harvey Anderson, District Sales Manager, serves principally the company's Chlorine and caustic soda customers in Wisconsin and Minnesota.

External Fan Cooled Motor

408

Sterling Electric Motors, Inc., Los Angeles, Calif., is introducing a new improvement on the company's "Slo-Speed" geared motors. This new type geared motor is of the single reduction, "Klosd-Tite" construction for atmospheres containing non-explosive dusts, vapors and injurious foreign materials. An external fan forces powerful cooling blasts of air over the streamlined case. Output shaft ratings are the six AGMA speeds starting at 780 rpm. down to and including 280 rpm.; the motor can be mounted in any position without modification.

Davey Elects Warner

Davey Compressor Co., Kent, Ohio, elected W. W. Warner as vice president according to Paul H. Davey, President.

Mr. Warner had previously served as chief engineer of the company for 23 years. He was instrumental in conjunction with Mr. Davey in developing the world's first air cooled portable compressor and "Auto-Air" compressors driven from truck engines through split-propeller power take-offs.

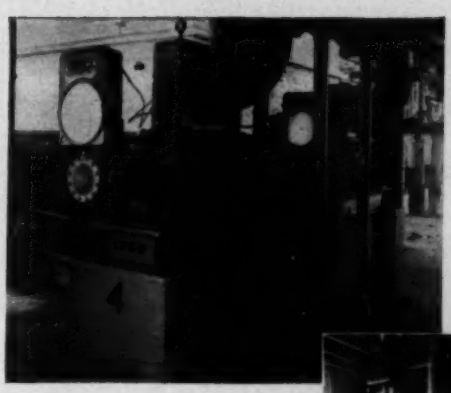
Conoflow Appoints Simpson & Co.

Conoflow Corp., Philadelphia, Pa., has announced the appointment of J. R. Simpson and Company, 600 South Michigan Avenue, Chicago, as Conoflow representatives.

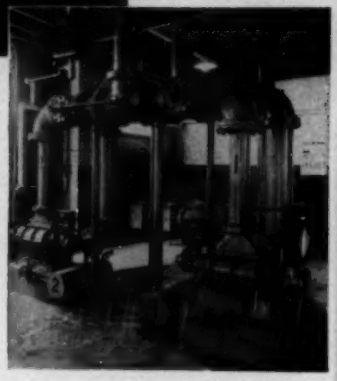
In addition to the Chicago area, J. R. Simpson & Company—headed by Mr. J. Robert Simpson, Jr.—will operate in Illinois, Indiana, and Wisconsin.

Cochran Acquires Pottstown Metal Products Co.

Cochrane Corp., Philadelphia, Pa., has announced the acquisition of Pottstown Metal Products Co., Pottstown Pa., which will be operated as an independent subsidiary of the Cochrane Corp. The transaction, which acquired practically all of the



Part of an installation of nine R-C Meters in a large plant, some of which date back 10 years or more. Capacities range from 3,000 cfh to 130,000 cfh.



YOU CAN ALWAYS

trust

R-C METERS

Continued repeat orders for R-C Positive Displacement Meters indicate the complete confidence of sewage treatment plant operators in the unvarying reliability of these units. Many have been installed so long that the original dates have been forgotten—yet they continue to measure as dependably as the day they were first put into service. That is because:

1. Accuracy is not affected by variations in specific gravity, rate of flow, pulsation, moisture, impurities or uncontrollable factors.
2. Accuracy is not subject to adjustment of meter or recorder by operators or other persons.
3. Accuracy is not affected by reasonable overloads.
4. Accuracy is permanent because measuring chambers are surrounded by precision-machined, cast iron surfaces.

Compactness of R-C Meters permits installation in cramped spaces. Sizes from 4,000 cfh to 1,000,000 cfh provide range for all sewage treatment applications. Indicating and recording devices are available. Ask for details in Bulletin 40-B-14 or write us about your needs.

ROOTS-CONNERSVILLE BLOWER CORPORATION
510 Mount Avenue, Connersville, Indiana

ROOTS-CONNERSVILLE

BLOWER BUILDERS SINCE 1854

ONE OF THE DRESSER INDUSTRIES

If interested in equipment or literature mentioned above, mail a Reader Service Card with your name, address, and item key number.

INSURE YOUR FILTER
AT NO COST
by using our
FILTER SAND and GRAVEL
FOR WATER AND SEWAGE PLANTS

Close attention to detail by experienced men and new modern equipment insure both the quality and prompt shipment of all orders. Our method of shipping in bulk prevents mixing of sizes in transit.

SHIPMENT IN BAGS WHEN PREFERRED

Try us on your next order.

NORTHERN GRAVEL COMPANY
P. O. Box No. 307, Muscatine, Iowa

LEADITE
The Pioneer Self Caulking Material for C. I. Pipe

4 REASONS
why more miles of cast iron water mains are jointed with LEADITE than with any other melted self-caulking material:

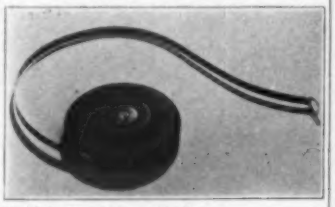
- MELTS EASILY
- GOES FARTHER
- SAVES TIME, LABOR, COST OF MATERIAL
- MAKES A GOOD TIGHT JOINT THAT IMPROVES WITH AGE !

THE LEADITE COMPANY
Girard Trust Co. Bldg., Philadelphia 2, Pa.

No Caulking

capital stock of the Pottstown Company, was for cash. Organized in 1927, Pottstown has been one of Cochrane's principal sources for steel heater, softener and filter shells and for numerous weldments. Many other firms have been customers of Pottstown in the past and it is planned to develop that phase of the business and to widen the scope of the company's activities.

T. E. McBride, President of the Cochrane Corp., becomes president and treasurer of Pottstown Metal Products, V. A. Rohlin is vice president, Raymond A. Piersol is vice president and general manager, and George Mease is plant superintendent.



Self-Retracting Rule

409

Master Rule Manufacturing Co., Inc., Middletown, N.Y., has developed a new 50-foot steel-tape rule called the Master Longboy-050 that rewinds automatically. It is reported to be the first field tape which requires neither hand cranking nor reeling.

The Longboy rewinds with a constant retracting torque, whether the full 50 feet or only the last inch is out—a virtue made possible by the incorporation of the new neg'ator-type spring in its planetary coiling mechanism. Simple thumb pressure on the center plate-button starts the rewind; release of this pressure stops the action instantly. Thus, the moving tape is under full control at all times, and only one hand is required for manipulation (even in cold weather with heavy gloves or mittens). Rewind force is sufficient to draw the tape through any terrain, including wet sand and high grass. Cleaning is accomplished with dispatch by running the tape through oily cloth held in the left hand as the rewind proceeds.

Worthington Elects Haslam

Worthington Pump & Machinery Corp., Harrison, N.J., elected Robert T. Haslam to the Board of Directors, according to an announcement by H. C. Ramsey, President.

Mr. Haslam was, until recently, a vice president and director of Standard Oil Company (N.J.), a director and member of the executive commit-

OMEGA

THE LAST WORD IN FEEDERS . . .
— for alum, lime, soda ash, ferric sulphate, sodium fluoride, carbon, and other water treatment chemicals. For Bulletins and complete information, address Omega Machine Company, (Division of Builders Iron Foundry) 350 Harris Ave., Providence 1, R. I.

OMEGA MACHINE COMPANY

Tegul MINERALEAD®
HYDRORINGS
HYDROPAC
GK sewer jointing compound

A complete line of jointing materials and accessories for water and sewer pipe. Specific bulletins and Technical Service available to help solve your problems.

Write 24 Walnut Street, Mertztown, Pa.

Over a half century of service

Atlas
MINERAL PRODUCTS COMPANY
MERTZTOWN, PA. HOUSTON, TEXAS

If interested in equipment or literature mentioned above, mail a Reader Service Card with your name, address, and item key number.

tee of Ethyl Corp.; he also is a member of the Corporation of Massachusetts Institute of Technology.

Graduating from M.I.T. in 1911 with a B.S. degree in chemical engineering, Mr. Haslam then joined its faculty. He later became professor of Chemical Engineering, in charge of the School of Chemical Engineering Practice before joining Standard Oil Company (N.J.)

Mathieson Appoints Synan

Mathieson Chemical Corp., Baltimore, Md., has appointed John F. Synan, manager of the product development department; he will report to Dr. George P. Vincent, director of product development.

Mr. Synan, who has been with Mathieson since 1939, is known for his developments involving the chlorine dioxide method for removing tastes and odors in drinking water and also for Textone, a sodium chlorite product for textile processing.

Dooley Rockwell's Tulsa Meter Supervisor

Rockwell Manufacturing Co., Pittsburgh, Pa., has announced the appointment of A. M. Dooley as Water Meter Sales Supervisor for the Tulsa area.

Mr. Dooley was born and educated in Clinton, Missouri, and for the last 35 years he has been in a sales and supervisory capacity for various concerns. Before joining Rockwell he was State Representative for N.A.P.A. Insurance Co., Store Supervisor for L.G.A. stores in Kansas and Oklahoma, Field Representative for J. A. Folger & Co., and affiliated with a water meter company for several years.

Hagan Opens New Office

Hagan Corporation, Pittsburgh, Pa., has announced the establishment of a new Chicago district office at 1463 Monadnock Building, 53 W. Jackson Blvd., Chicago 4.

The new office will also be the Chicago headquarters for Hagan's subsidiaries, Hall Laboratories, Inc., Calgon, Inc., and the Buromin Company.

Wherever

WASTE WATER

creates a problem

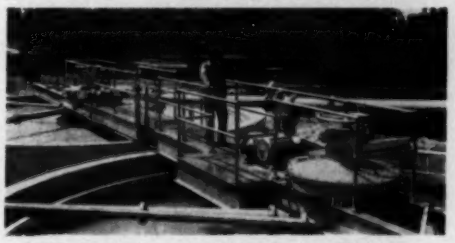
HARDINGE CLARIFIERS *or* **THICKENERS** *can solve it*

Hardinge has installed waste water treating or reclaiming equipment for the following industrial operations:

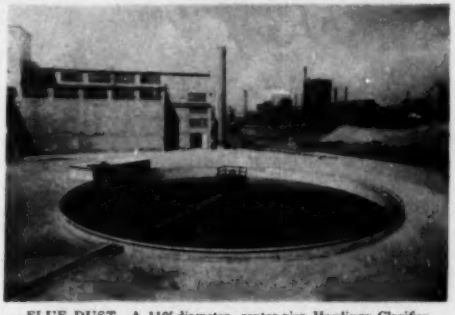
COAL
PAPER
OIL
GLASS
LIME
STONE
SAND
FLUE DUST
CARBON BLACK
MEAT PACKING
RUBBER
DOMESTIC SEWAGE

Write for Bulletin 35-C-15

COAL—120'-diameter Hardinge Clarifier for removing 60 tons per hour of solids from coal breaker waste water.



LIME—Two 32'-diameter by 15'-deep Hardinge Thickeners reclaiming calcium carbonate for lime production from clarifier underflow in a water-treating plant.



FLUE DUST—A 110'-diameter, center-pier Hardinge Clarifier recovering 50 tons per day of usable solids from blast furnace flue wash water in a steel plant.

PAPER—30'diameter Hardinge Thickener recovering 2 to 2½ lbs. of fiber and filler per 1,000 gallons of paper plant waste water.

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COMPANY, INCORPORATED

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New Hyde Park New York

Remote Control For Power Drives

410

Sterling Electric Motors, Inc., Los Angeles, Calif., has announced a new electric Remote Control for Sterling Speed-Trol (Variable Speed) Electric Power Drives. This is a package unit design, which may be mounted on any size Speed-Trol of current design by the user in the field as well as being available with new Speed-Trols at the factory.

The package unit includes a mounting bracket, reversing motor, chain and sprockets, friction clutch, chain guard, and remote "Fast—Slow" station. It is available either with or without an Electric Remote Speed Indicator.

Speed-Trol Electric Power Drives are available in ratings of ¼ hp. to 25 hp. inclusive and are manufactured with 2:1, 3:1, or 4:1 speed variation in a range of speeds from 2000 down to 26 rpm.

C.I. Soil Pipe Institute Opens Washington Offices

Cast Iron Soil Pipe Institute, according to Robert Dick, executive secretary, has opened the Washington offices of the Institute in the Heurich Building at 1627 K Street N.W., Washington 6, D.C.

Wheeler Appoints Yetter

C. H. Wheeler Mfg. Co., Philadelphia, Pa., has anonunced the appointment of F. L. Yetter as Senior Vice President.

Mr. Yetter rejoins the company after a twenty month period during which he served as Director of Foreign Affiairs for the Kuljian Corp. He has long been associated with the power plant field, having started with De Laval Pump Co., in 1913, changing to the Alberger Pump and Condenser Co., in 1915, and beginning his long tenure of service with Wheeler in June 1916.

Conoflow Appoints Koch V.P.

Conoflow Corp., Philadelphia, Pa., has announced the appointment of John C. Koch to Vice President in

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Charge of Sales. Mr. Koch, who joined Conoflow in 1945, has been acting in the capacity of General Sales Manager in Philadelphia until his recent promotion. Previously associated with one of the major instrument companies, he has been active in sales engineering work in the industrial control field for many years. A member of the Instrument Society of America, Mr. Koch attended Rensselaer Polytechnic Institute.

Tube Turns Appoints Bethlehem Supply

Tube Turns, Inc., has announced the appointment of the Bethlehem Supply Co., and the Bethlehem Supply Co., of Calif., as distributors of Tube-Turn welding fittings and flanges.

The Bethlehem Supply Co. is a subsidiary of the Bethlehem Steel Co. and has its main offices in Tulsa. Its oil country stores and service organization covers Arkansas, Colorado, Illinois, Kansas, Louisiana, Mississippi, New Mexico, Oklahoma, Texas and Wyoming.

Fire Extinguisher for Electric Motors

411

Ansul Chemical Co., Marinette, Wis., has developed a Dry Chemical Fire Extinguisher that is said to be especially effective in putting out fires in electric motors and generators without hazard to employees.

After the flames have been extinguished the windings and framework may be covered with a deposit of dry chemical, but, according to the company, this residual is easily removed by air stream or brush.

The company states that the prompt application of dry chemical to a motor or generator which has been subjected to an electrical failure will quickly extinguish the flames and, by preventing reflash, will stop the spread of flames to windings not involved in the original failure.

Hagan Names Two To Board

Hagan Corp., Pittsburgh, Pa., has announced that two veteran employees have been elected to the Board of Directors of the Corporation and its subsidiaries, Hall Laboratories, Inc., and Calgon, Inc.

R. R. Donaldson joined the Hagan organization in 1919, one year after it was founded, as a service engineer. He was advanced to chief engineer in 1945 and was elected vice-president in charge of engineering in 1948.

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WHAT part of industry's six billion dollar corrosion bill are you paying? Any amount is too much and can be cut considerably through the installation of saran lined steel pipe. You will find, as have many of the country's leading manufacturers, that saran lined steel pipe means dependable, long term operation. In addition to the excellent corrosion resistance of this remarkable pipe —you have the plus values of rigidity, pressure strength and ease of installation, requiring NO special tools. These advantages are all important to you in the reduction of shut-down time, lost production and equipment replacement.

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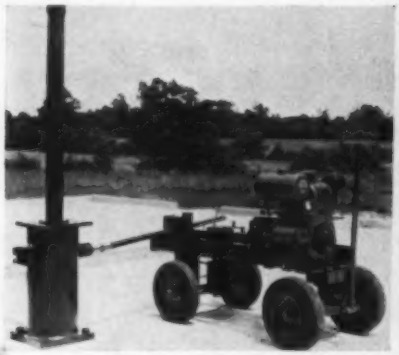

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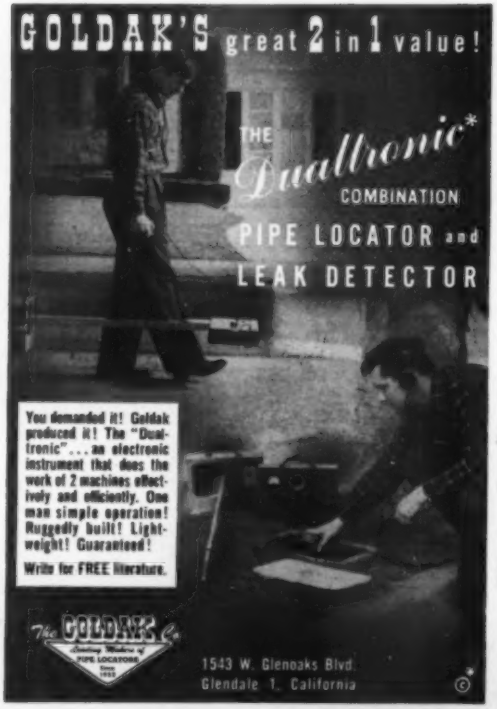
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Dr. Everett P. Partridge joined Hall Laboratories, Inc., in 1935 as research director. He was elected director of Hall Laboratories in April 1950, succeeding Dr. R. E. Hall.

Literature and Catalogs

Feed Water Control

412

Bailey Meter Co., Cleveland, Ohio, has published a 16 page bulletin describing the latest developments in **Bailey Three-Element Feed Water Control.** This attractive three-color bulletin contains a straightforward, concise discussion of problems encountered in Feed Water Control and explains how the Bailey Air-Operated Three-Element System helps solve them.

Diagrams, cutaway views, typical chart records and photographs of modern installations are used liberally to aid in describing the control system.

Sand Filter-Clarifier

413

Hardinge Co., Inc., York, Pa., has just published a four-page bulletin covering its line of **Sand Filter-Clarifiers.**

The bulletin states that this new filter-clarifier is quite different from the Hardinge Automatic Backwash Sand Filter, as the Hardinge Filter-Clarifier is not a backwash type filter, but uses, instead, a spiral scraper that takes a cut off the sand bed when the filter rate decreases.

Operating principles, typical performance data, capacities and advantages are discussed and a cut-away photo-drawing and line drawings of the unit complete the bulletin.

Valve Catalog

414

Stockham Valves and Fittings Co., Birmingham, Ala., has issued a new **Valve Catalog 50V,** describing for the convenience of all specification writers and purchasers the entire Stockham line of bronze and iron body valves. This concise new catalog has been planned for quick, easy reference. In make-up, it closely approximates the 1950 catalog and conforms to the page size endorsed by the National Association of Purchasing Agents and the American Institute of Architects. Listings are

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complete for the valves shown on each page and include photographs, dimensional diagrams, price, weight, sizes and dimensions.

A section completely describing accessories and several pages of essential engineering data complete the 112-page fabrikoid-bound catalog, which is thoroughly indexed.

Water Pressure Reducing Valve

415

Golden-Anderson Valve Specialty Co., Pittsburgh, Pa., has just released a 6-page bulletin containing complete technical information on its **Cushioned Water Pressure Reducing Valve.**

The bulletin features the general arrangement of the Golden-Anderson Cushioned Water Pressure Reducing Valve and the Reducing Pilot Valve, with a detailed list of parts. The installation, operation, adjustment, servicing and specifications are fully described, along with tables showing general dimensions, approximate shipping weights and general list of materials.

Lime Hydrator

416

Hardinge Co., Inc., York, Pa., has just published an 8-page catalog describing its new **Continuous Lime Hydrators.** The Hardinge Hydrators, according to the catalog, combine the most desirable features of the Schulthess, McGann and Kuntz Hydrators, manufacturing rights for which have recently been acquired by the Hardinge organization. The bulletin covers the theory of lime hydration, as well as construction details, dimensions and capacities of Hardinge Hydrators. It also discusses, briefly, other Hardinge equipment for the lime industry: vertical and horizontal-rotary lime kilns, tube mills for hydrate grinding, conical mills for limestone reduction, continuous rotary dryers and regulating feeders.

Well Water Systems

417

Layne & Bowler, Inc., Memphis, Tenn., has published an attractive 48 page, 4-color booklet covering **Layne Well Water Systems.** It is profusely illustrated with photographs and drawings showing the Layne methods of drilling deep water wells.

The booklet discusses: gravel wall wells, cemented wells, tubular and rock wells, special drilling, shutter

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For Concrete and Tile

Complete, Economical Protection

Above, A-2-13 Clark Meter Box Cover with screw lock. Height 4" lid opening 13"

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Right, B-2-11-L Clark Double Lid Meter Box Cover, 6" throat. Also available in 4" and 9" throat.

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Improved Screw Lock with strong forged bronze bolt.

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Combination Key, available in meter and service box sizes.

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940

Write for Bulletin

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screens for gravel wall wells, vertical turbine pumps, water treatment and water conditioning.

A description of the complete Layne service is included in the back of the book along with engineering and useful data tables concerning wells and water. The booklet is punched for inclusion in a three ring binder and lists all of the Layne associated companies.

Vari-Pitch Drive

418

Allis-Chalmers Manufacturing Co., Milwaukee, Wis., has just published a 12-page bulletin on the **Automatic Vari-Pitch Sheaves.** The bulletin describes the drive as a simple, low-cost method of instant speed control covering most speed changing needs from 1½ to 40 horsepower. According to the bulletin, to increase the speed, when employing the drive, it is only necessary to move the motor. Belt tension is automatically maintained and a speed variation of approximately 2 to 1 is possible.

The bulletin carries instructions and tables to enable individuals to figure the components needed to assemble a drive for almost any speed range and horsepower within the range of this drive.

High Capacity Chlorinizer

419

Builders-Providence, Inc., Providence, R. I., has issued a new bulletin on the new **Model HCVS Volumetric Chlorinizer.** This 4-page bulletin describes the high capacity visible flow Chlorinizer which is designed to meter chlorine gas accurately at rates up to 6000 pounds per 24 hours.

The bulletin lists the many features of the Chlorinizer and shows a cut-away drawing of the functioning parts. An easily readable diagram shows how the operation of the Chlorinizer is carried out. There is also a discussion of operation of the rate of flow indicator, low maintenance costs, and installation.

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a clear liquid penetrating (1"+) sealer for concrete and masonry preventing water absorption and reducing the action of acids. Holds 12' hydrostatic head. Use our Hayproc Rubberized Enamel for color on walls and floors—not affected by concentrated acids, alcohol, oil, or traffic abrasion.

30 OTHER PRODUCTS

Write for technical data.

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See our file in Sweet's

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A Filter Medium For All Purposes

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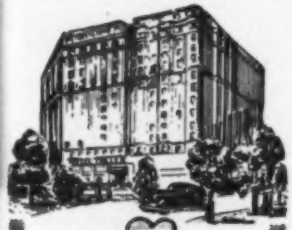
822 E. 8th St. Erie, Pa.

Engineers and Sales Agents



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Graduate engineer, preferably with water plant experience, to be in charge of pumping station and purification plant, including doing of laboratory work. 18 M.G.D. plant treats Lake Michigan water. Future advancement possible. Reply should give full particulars as to applicant's education and experience, age, family status, and salary required. Address: J. C. Zufelt, Sup't., Board of Water Commissioners, Sheboygan, Wisconsin.

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Meetings Scheduled:

(Continued from page 116A)

Sept. 19-21—St. Joseph, Mich. *(Whitcomb Hotel)* MICHIGAN SECTION A.W.W.A. Sec'y, T. L. Vander Velde, 2609 E. Saginaw Street, Lansing 12, Mich.

Sept. 19-21—Yankton, S. Dak. *(Charles Gurney Hotel)* SOUTH DAKOTA SECTION A.W.W.A. (Joint Meeting) SOUTH DAKOTA SEWAGE WORKS ASSOCIATION. Sec'y, Chas. E. Carl, State Board of Health, Pierre, S. Dak.

Sept. 24-25—Denver, Colo. *(Cosmopolitan Hotel)* ROCKY MOUNTAIN SECTION A.W.W.A. Sec'y, Geo. J. Turre, P.O. Box 600, Denver, Colo.

Sept. 26— ROCKY MOUNTAIN SEWAGE WORKS ASSOCIATION. Sec'y, Carrol H. Coberly, 1441 Welton St., Denver, Colo.

Sept. 24-26—Biloxi, Miss. *(Buena Vista Hotel)* ALABAMA-MISSISSIPPI SECTION A.W.W.A. Sec'y, Chas. W. White, 519 Dexter Ave., Montgomery, Ala.

Sept. 25-27—Milwaukee, Wis. *(Hotel Pfister)* WISCONSIN SECTION A.W.W.A. Sec'y, Leon A. Smith, City Hall, Madison 3, Wis.

Sept. 26-28—Fargo, N.D. *(Gardner Hotel)* NORTH DAKOTA WATER & SEWAGE WORKS CONFERENCE. Sec'y, Jerome H. Svore, State Dept. of Health, Bismarck, N.D.

Sept. 27-28—Saskatoon, Sask. *(Bessborough Hotel)* WESTERN CANADA WATER & SEWAGE CONFERENCE. Sec'y, H. C. Lindsten, 301 Hamilton Bldg., Winnipeg, Can.

Sept. 27-28—Toledo, Ohio *(Commodore Perry Hotel)* OHIO SECTION A.W.W.A. Sec'y, F. P. Fischer, 812 Perry Payne Bldg., Cleveland 13, Ohio.

Oct. 8-11—St. Paul, Minn. *(Municipal Auditorium)* FEDERATION OF SEWAGE & INDUSTRIAL WASTES ASS'NS. (Annual Convention) W. H. Wisely, 325 Illinois Building, Champaign, Ill.

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Maintains exact levels to 1/100 of an inch in **Water Tanks—Reservoirs—Settling Basins—Boilers—**

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Write for Engineering bulletin No. 421

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ECONOMICAL—Power input varies with volume of air required. Retain original efficiency indefinitely—deliver full rated capacity continually.

ALL CAPACITIES UP TO 10,000 C. F. M. AND VARIOUS AIR PRESSURES UP TO 8 LBS.

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Div. TENNESSEE CORPORATION
Box 3269 Tampa 1, Fla.

Recooling Spray Nozzle Systems

420

Schutte and Koerting Co., Cornwells Heights, Pa., has published a bulletin picturing and describing **Recooling Spray Nozzle Systems.**

The eight page bulletin details design, application, construction, and operation of SK spray nozzles, and diagrams typical spray pond arrangements. Sizes, dimensions, capacities, and spray nozzle patterns are included in tabular form for each nozzle size.

A temperature graph gives cooling performance curves for the nozzles for various temperature ranges using 7 psi. at the nozzle. Atmospheric conditions and operating pressures are discussed in the text material.

The bulletin also diagrams and describes SK Louvre Screens which are designed to prevent spray from being carried away by wind, while at the same time providing for maximum air passage for cooling.

Porous Media

421

The January issue of this magazine carried an announcement that the Carborundum Co., Perth Amboy, N.J., had issued a 56-page, two-color handbook on **Porous Media for Filtration and Diffusion.** Unfortunately a late problem of make-up made it necessary to split the announcement between two pages separated by ads. Perhaps some of our readers missed the announcement.

For that reason we'd like to say again that this book discusses in detail the successful use of "Aloxite" (Aluminum Oxide). Porous Media in water and sewage treatment.

The booklet is profusely illustrated with charts, drawings and photographs and will prove a valuable asset to the library of anyone concerned with porous media.

Divided into four sections it covers General Data, Filtration, Diffusion and Specifications.

FOR SALE

Subject to prior sale, we offer approximately 14,370 feet of 14" Cast Iron, Second Hand Class "B", 150# Water Service Pipe, located Sedalia, Missouri. Inspection invited. If interested please advise.

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10" Class B—14,736 feet

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The age-old problems of maintenance and replacement are solved when you specify CARLON plastic pipe for municipal water systems, sewage disposal, land drainage and other medium-pressure, low temperature applications.

CARLON plastic pipe is guaranteed against rot, rust and electrolytic corrosion. It will not accumulate scale or sediment, is inert to the action of corrosive soils and waters, and features a projected service life many times longer than ordinary pipe.

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When pipe life is too short, eliminate costly maintenance and replacement problems . . . Specify CARLON—The first real pipe that is plastic!

At present, raw material shortages are limiting the production of certain types of CARLON pipe. Every effort is being made, however, to overcome this problem and to meet the demand and need for CARLON plastic pipe.

CARLON CP 128-CP

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Emblem Awards Booklet

422

American Emblem Co., Utica, N. Y., has just published a new booklet entitled **"How Service Awards Promote Loyalty."** The booklet which reproduces in full color a wide variety of pin and button awards, was designed to reveal to employers who have not used emblem awards in the past, the various types and designs now part of the loyalty building programs of some of the leading industrial, business and institutional organizations in the United States.

Liquid Level Gauges

423

Bristol Co., Waterbury, Conn., has just published a new 24-page bulletin on **Water Level Gauges.** The bulletin describes instruments for measuring and recording water depth in reservoirs, elevated tanks, rivers, lakes, irrigation systems, process storage tanks, forebay and tail races, flumes, and weirs. Float, pressure, bulb, counterpoise, differential pressure, and air-bubbler types of liquid level gauges for a variety of uses are described.

Discussed in the bulletin is the measurement and automatic control of water and other liquids and solutions, whether flowing, turbulent, corrosive, under static pressure, covered with ice, or carrying solid matter. Applications of the instruments to chemical processing operations involving solutions, suspensions, and organic liquids are included.

High-Speed Synchronous Generators

424

General Electric Co., Schenectady, N.Y., has made available a new four-page, two color bulletin on **Tri-Clad High-Speed Synchronous Generators.**

The bulletin covers generators for standby, portable, and prime-source power in ratings from 1.875 to 50 kva with frequencies of 60 and 400 cycles. Four designs are described: externally-regulated, self-regulated and packaged-regulated 4-pole synchronous generators, and high-frequency 14-pole synchronous generators.

Well illustrated with product pictures as well as cut-away and exploded-view photographs, the publication enumerates construction features of the new generators and includes a comparison table of ratings.

Regulators

425

Spence Engineering Co., Inc., Walden, N.Y., has just made available a new 4-page folder which gives useful information on **Spence Temperature Regulators, Pressure Regulators, and Desuperheaters.**

A complete explanation of the principles of pilot-operated regulating valves is given in this folder in addition to data and illustrations of 27 different Spence pilots.

Pipe Insulation Efficiency

426

Union Asbestos & Rubber Co., Chicago, Ill., has made available a slide-rule type of chart called **Fact Finder** which shows at a glance the Btu loss, Surface Temperature and Efficiency of Unibestos Pipe insulation.

The chart covers pipe sizes from 1 to 18 inches and covers insulation thicknesses from standard to 3½ inches. Temperature ranges of pipe to be insulated are shown from 300 to 1200° F. Also included is a diagram covering the Btu loss, surface temperature and efficiency of Unibestos Insulating Block.

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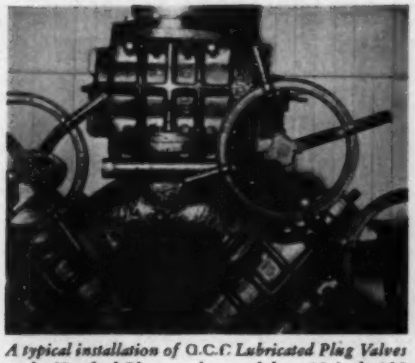

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Corrugated Metal Pipe

427

Armco Drainage & Metal Products, Inc., Middletown, Ohio, has published a new 16 page booklet entitled **Armco Corrugated Metal Pipe —A Type for Every Need.**

The booklet lists the types of full-round pipe and Pipe-Arch available to meet the specific requirements for various types of sewers, culverts, conduits or irrigation systems, and contains reference data for assistance in selecting the most suitable structure.

Photographs and case-histories show where plain galvanized, asphalt coated, asbestos-bonded and paved-invert pipe and Pipe-Arch have given long service life under all types of conditions. Also included are details on fittings and instructions on the installation of Armco drainage structures.

Master Controls

428

Pike Hoffman Control Co., Inc., St. Paul, Minn., has just issued a 15-page bulletin on **Master Controls** for water, sewage, industrial and pressure fields.

The bulletin discusses: Tankmaster for single and multiple pump control for regulating water levels in remote tanks; Sequence Master, an automatic pump or circuit sequence changer for one to four circuits; Hydromaster, for single and multiple pump and air control of hydropneumatic tanks; Pumpmaster, for multiple pump programming of automatic sewage pump control; Floatmaster, the multiple circuit float control for the operation of pumps, alarms and valves; Junior Master Float Switches for pumping in or out of tanks; and Signalmaster for alarm silencers, manual or automatic reset.

Photographs of all the items of equipment and ordering specifications complete the bulletin.

Steel Flooring

429

Dravo Corp., Pittsburgh, Pa., Machinery Div., has just released a new catalog describing various types of **Tri-Lok Open Steel Flooring and Armoring.** This attractive 2-color, 15 page catalog discusses the different types of Tri-Lok open steel flooring and safety treads. It contains specification data, safe load tables, installation methods and photographs of actual installations.

Also included is descriptive information on floor armoring and the Tri-Lok flooring which is an assembly of Tee Bars, which when filled with concrete, is used instead of heavy concrete flooring, reducing the dead load and thus permitting a lighter weight superstructure.

Anti-Corrosion Coating

430

Industrial Metal Protectives, Inc., Dayton, Ohio, has just published a bulletin on **Zincilate,** which is, according to the company, the one-coat self-protecting, anti-corrosion coating which provides corrosion resistance superior to conventional zinc coatings at lower cost.

The bulletin presents case histories on typical applications showing Zincilate's resistance to sever abrasive and corrosive conditions; complete specifications for the two Zincilate formulations; data on surface preparation and methods of application and an offer to provide process engineers to investigate corrosion problems and supervise applications.

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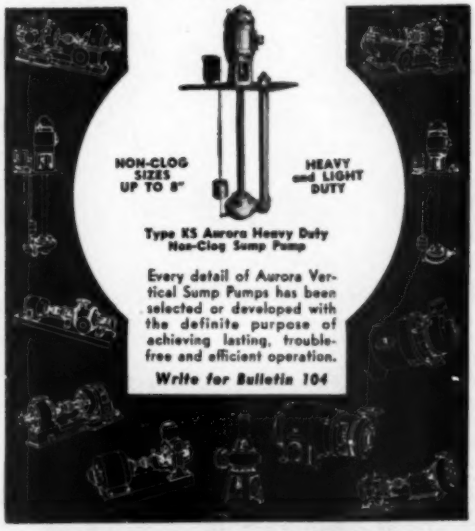
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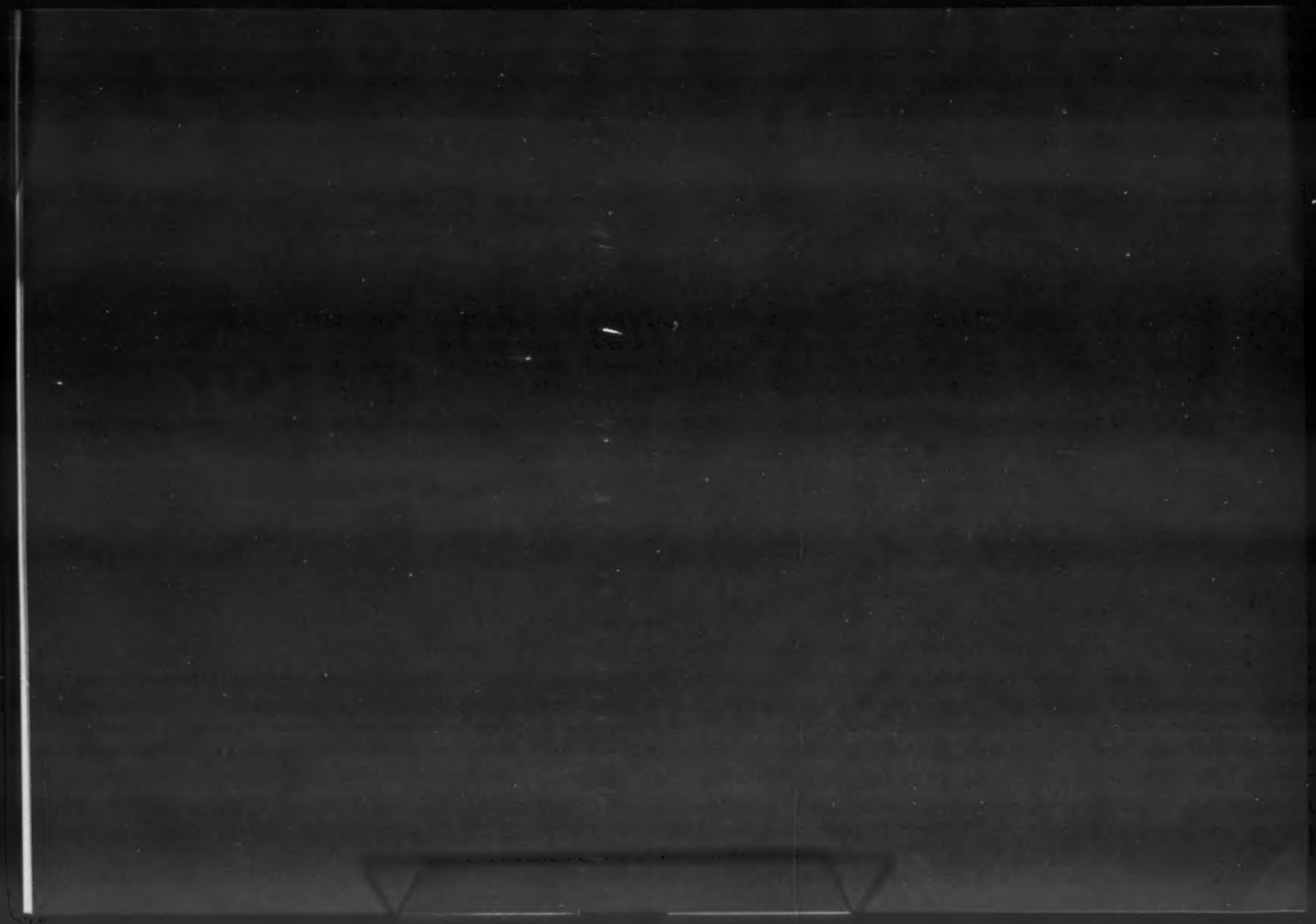

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AGITATORS
Allen-Billmyre Div., Lamson Corp., Syracuse 1, N. Y.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
H. D. Fowler Co., Inc., 901 Lane St. (P.O. Box 3084), Seattle, Wash.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Phipps & Bird, Inc., 303 S. Sixth Street, Richmond, Va.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., Aurora, Ill.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

AIR BLOWERS
(See Blowers, Air)

AIR COMPRESSORS
(See Compressors, Air)

AIR RELIEF VALVES
Crane Co., 836 So. Michigan Ave., Chicago 5, Ill.
Darling Valve Co., Williamsport, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Iowa Valve Co., Oskaloosa, Iowa.
R. S. Products Corp., Wayne Junction, Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Valve and Primer Corp., 127 N. Dearborn St., Chicago 2, Ill.

ALLOYS—COPPER—SILICA
American Brass Co., Waterbury, Conn.

ALTERNATORS, ELECTRIC
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
B/W Controller Corp., 2206 E. Maple Rd., Birmingham, Mich.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
General Electric Co., Schenectady, N. Y.
Healy-Ruff Co., 783 Hampden Ave., St. Paul, Minn.
Westinghouse Electric & Mfg. Co., P. O. Box 868, Pittsburgh 30, Pa.

ALUM
(See Black Alum or Filter Alum)

ALUMINUM & ALUMINUM ALLOY PRODUCTS
Aluminum Co. of America, Pittsburgh 19, Pa.
R. D. Cole Mfg. Co., Newnan, Ga.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kansas

AMMONIA, ANHYDROUS & AQUA
Dow Chemical Co., Midland, Mich.
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector Street, New York 6, N. Y.
Mathieson Chemical Corp., Mathieson Bldg., Baltimore 3, Md.
Penn Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

AMMONIATORS
Amer. Water Softener Co., Philadelphia 33, Pa.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 54, Calif.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Wallace & Tierman, Newark 1, New Jersey

ANTHRAFILT
Amer. Water Softener Co., Philadelphia 33, Pa.
Anthracite Equip. Co., Anthracite Institute Bldg., Wilkes-Barre, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., Aurora, Ill.

AQUAPHONES
Globe Phone Mfg. Corp., 2 Linden St., Reading, Mass.
Northrup & Co., Inc., Spring Valley, N. Y.

ARRESTERS, FLAME
H. D. Fowler Co., Inc., 901 Lane St. (P.O. Box 3084), Seattle, Wash.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.

ASBESTOS-CEMENT PIPE
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Johns-Manville Co., 22 E. 40th St., New York City.
Keasbey & Mattison Co., Ambler, Pa.

ASH AND COAL HANDLING MACHINERY
Bucyrus-Erie Co., South Milwaukee, Wis.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dracco Corp., Cleveland, Ohio.
Frank G. Hough Co., 752 Sunnyside Ave., Libertyville, Ill.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus 46, Ohio
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

BAR SCREENS
(See Screens, Sewage)

BINS, STORAGE
R. D. Cole Mfg. Co., Newnan, Ga.
Hammond Iron Works, Warren, Pa.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus 46, Ohio
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Posey Iron Works, Inc., Lancaster, Pa.

BITUMINOUS COATINGS AND LININGS
Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Atlas Mineral Prod. Co., Mertztown, Pa.
Centriline Corp., 140 Cedar St., New York 6, N. Y.
Ebony Paint Manufacturing Co., 18th and Agnes Ave., Kansas City 1, Mo.
Insertol Co., Inc., 480 Frelinghuysen Ave., Newark 5, N. J.
Johns-Manville Corp., 22 East 40th Street, New York 16, New York
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Wailes Dove-Hermiston, Westfield, N. J.

BLACK ALUM
(See Activated Alum)

BLEACHING POWDER
(See Calcium Hypochlorite)

BLOWERS, AIR, GAS (Centrifugal and Rotary)
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Ill.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Dracco Corp., 4079 E. 116th St., Cleveland 5, Ohio.
General Electric Co., Schenectady, N. Y.
Homelite Corp., Port Chester, N. Y.
Lamson Corp., Blower Division, Syracuse 1, New York.
Roots-Connersville Blower Corp., P. O. Box 327, Connersville, Ind.
Standard Stoker Co., Erie, Pa.
U. S. Hoffman Mach. Corp., 111 Fourth Ave., New York 3, N. Y.

BLOWERS (Gasoline Engine Driven Portable)
Homelite Corporation, Port Chester, N. Y.
Lamson Corp., Blower Division, Syracuse 1, New York.
Roots-Connersville Blower Corp., P. O. Box 327, Connersville, Ind.

BOILER FEEDWATER TREATMENT AND EQUIPMENT
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 54, Calif.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
The Dorr Co., Barry Place, Stamford, Conn.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Heil'ige, Inc., 87-18 Northern Blvd., Long Island City 1, N. Y.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Liquid Conditioning Corp., 114 E. Price St., Linden, N. J.
Milton Roy Co., 1229 E. Mermaid Lane, Philadelphia 18, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Proportioneers, Inc., 345 Harris Ave., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Penn.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.

BOILERS, GAS
American Radiator & Standard Sanitary Corp., P. O. Box 1236, Pittsburgh 30, Pa.
R. D. Cole Mfg. Co., Newnan, Ga.

BOOKS, TECHNICAL
McGraw-Hill Book Co., 330 W. 42nd St., New York 18, N. Y.
The MacMillan Co., 60 Fifth Ave., New York 11, New York.
John Wiley & Sons, Inc., 440 4th Ave., New York 16, N. Y.

BOXES, VALVE AND METER
(See Valve Boxes; Meter Boxes)

BRASS GOODS
(See also Pipe, Brass)
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Glauber Brass, Inc., Kinsman, Ohio
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., E. Orange, N. J.

BREECHINGS, STEEL
Chicago Bridge & Iron Company, 2199 McCormick Bldg., Chicago.
R. D. Cole Mfg. Co., Newnan, Ga.
Littleford Bros., Inc., 453 E. Pearl St., Cincinnati 2, Ohio.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Posey Iron Works, Inc., Lancaster, Pa.

BUFFER SOLUTIONS & TABLETS
Beckman Instruments, Inc., 820 Mission St., South Pasadena, Calif.
Coleman Instruments, Inc., 318 Madison St., Maywood, Ill.
Heilige, Inc., 87-18 Northern Blvd., Long Island City, N. Y.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.

BUCKET ELEVATORS
Chain Belt Co., 1610 W. Bruce St., Milwaukee, Wis.
Dorr Co., Barry Place, Stamford, Conn.
Link-Belt Co., 2045 Hunting Park Ave., Philadelphia 40, Pa.
Omega Machine Co., 345 Harris Avenue, Providence 1, Rhode Island.
Stuart Corp., 516 N. Charles St., Baltimore, Md.
Walker Process Equip., Inc., Aurora, Ill.

BUTTERFLY VALVES
(See Valves, Butterfly)

CABLE
General Electric Corp., Schenectady, N. Y.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

CALCIUM HYPOCHLORITE
Innis, Speiden & Co., 117 Liberty St., New York City.
John Wiley Jones Co., Caledonia, N. Y.
Mathieson Chemical Corp., Mathieson Bldg., Baltimore 3, Md.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Pittsburgh Plate Glass Co., Columbia Chemical Division, Fifth Ave., at Bellefield, Pittsburgh.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.

CALGON
(See Corrosion Suppression and Water Stabilization)

CAULKING MACHINES & TOOLS
W. S. Darley & Co., 2810 Washington Blvd. Chicago 12, Ill.
Mueller Co., Decatur 70, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.

CARBON-ACTIVATED
(See Activated Carbon)

CARBONATORS (Recarbonation).
Amer. Well Works, 100 N. Broadway, Aurora, Ill.
Carborundum Co., Perth Amboy, N. J.
Chicago Pump Co., 2306 Wolfram Street, Chicago 18, Illinois. Aurora, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Walker Process Equipment Co., Aurora, Ill.

CASTINGS, IRON, STEEL, ALLOY STEEL, ETC.
Bethlehem Fdry. & Machine Co., Bethlehem, Pa.
Cast Iron Pipe Research Assoc., 122 So. Michigan Ave., Chicago.
Central Foundry Co., 366 Fourth Ave., New York, N. Y.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
The Filer & Stowell Co., 147 E. Becher Street, Milwaukee 7, Wisconsin.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hardinge Mfg. Co., 240 Arch St., York, Pa.
Lee Hydraulic Co., P.O. Box 804, Troy, N. Y.
Posey Iron Works, Inc., Lancaster, Pa.
Richmond Fdry. & Mfg. Co., P.O. Box 5150, Saunders Sta., Richmond, Va.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N.J.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 55 Liberty Street, New York 5.

CAST IRON PIPE
(See Pipe)

CATHODIC PROTECTIVE SYSTEMS
Chicago Bridge & Iron Co., 332 South Michigan Ave., Chicago.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Electro Rust-Proofing Corp., (N. J.), Belleville, N. J.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.

CEMENT ASBESTOS PIPE
H. D. Fowler Co., Inc., 901 Lane St., (P. O. Box 3084), Seattle, Wash.
Johns-Manville, 22 E. 40th St., New York City.
Keasbey & Mattison Co., Ambler, Pa.

CEMENT GUN
Cement Gun Co., Inc., 1520 Walnut Street, Allentown, Penna.
Preload Corp., 211 E. 37th St., New York 16, N. Y.

CEMENT PIPE
(See Pipe, Concrete)

CEMENT LINED PIPE
(See Pipe, Cement Lined)

CEMENT LINING OF PIPE
Centriline Corp., 140 Cedar St., New York 6, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

CEMENTS, ACID PROOF & ALKALI PROOF
Atlas Mineral Prod. Co., Mertztown, Pa.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7.

CEMENTS, REFRACTORY
Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.

CEMENTS, SEWER PIPE
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York, N. Y.
Northrop & Co., Inc., Spring Valley, N. Y.
Preload Corp., 211 E. 37th St., New York 16, N. Y.

CEMENTS, WATER MAINS
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York, N. Y.
Michael Hayman & Co., 570 E. Ferry St., Buffalo, N. Y.
Northrop & Co., Inc., Spring Valley, N. Y.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

CHAINS (Elevating, Conveying & Power Transmission)
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

CHEMICAL CONTROL EQUIP.
(See Laboratory Apparatus & Reagents)

CHEMICAL, CONVEYING EQUIPMENT
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dracco Corp., 4079 E. 116th St., Cleveland 5, Ohio.
Hardinge Co., Inc., 240 Arch St., York, Pa.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

CHEMICAL FEEDING & PROPORTIONING EQUIPMENT (Dry & Solution—Also see Chlorinators)
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
B/W Controller Corp., 2206 E. Maple Rd., Birmingham, Mich.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. 3084, Seattle, Wash.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Milton Roy Co., 1329 E. Mermaid Lane, Philadelphia 18, Pa.
Omega Machine Co., 345 Harris Avenue, Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Process Engineers, Inc., 321 Market St., San Francisco, Calif.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Roots-Connersville Blower Corp., P. O. Box 327, Connersville, Ind.
Simplex Valve & Meter Co., 6742 Upland St., Philadelphia, Pa.
R. W. Sparling, Box 3277, Terminal Annex, Los Angeles, Calif.
Wallace and Tiernan, Newark 1, New Jersey.

CHLORINATORS
(See also Hypochlorinators)
Amer. Water Softener Co., Philadelphia 33, Pa.
Builders - Providence, Inc., 350 Harris Ave., Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 54, Calif.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Milton Roy Co., 1329 E. Mermaid Lane, Philadelphia 18, Pa.
Omega Machine Co., 345 Harris Ave., Providence 1, R. I.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Wallace and Tiernan, Newark 1, New Jersey.

CHLORINE DIOXIDE
(See Sodium Chlorite)

CHLORINE, LIQUID
Diamond Alkali Co., 300 Union Commerce Bldg., Cleveland 14, Ohio.
Hooker Electrochemical Co., 9 Union St., Niagara Falls, N. Y.
John Wiley Jones Co., Caledonia, N. Y.
Mathieson Chemical Corp., Mathieson Bldg., Baltimore 3, Md.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, Fifth Ave. at Bellefield, Pittsburgh 13, Pa.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.
Solvay Sales Div., Allied Chemical & Dye Corp., 40 Rector Street, New York 6, New York.

CHLORINE CONTROL EQUIPMENT
(See Residual Chlorine Control)

CLAMPS AND SLEEVES, PIPE
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

CLAMPS, BELL JOINT
Carson-Cadillac Corp., 1221 Pinson St., Birmingham, Ala.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.

CLAMPS, PIPE REPAIR
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.

CLARIFIERS, SEWAGE AND WATER
American Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Dorr Co., Barry Place, Stamford, Conn.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago 6, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Avenue, Chicago 13.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Process Engineers, Inc., 321 Market St., San Francisco 3, Calif.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., Aurora, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

CLAY PIPE
(See Vitrified Clay Pipe and Products)

CLEANING COMPOUNDS
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
General Chem. Div., 40 Rector St., New York 6, N. Y.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Philadelphia Quartz Co., 1146 Public Ledger Bldg., Philadelphia 6, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, Fifth Ave. at Bellefield, Pittsburgh 13, Pa.
Solvay Sales Div., Allied Chemical & Dye Corp., 40 Rector Street, New York 6, New York.

CLEANING SEWAGE MAINS
(See Sewer Cleaning Equipment and Service)

CLEANING WATER MAINS
Flexible Underground Pipe Cleaning Co., 9059 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 50 Church St., New York City.
Pittsburgh Pipe Cleaner Co., 133 Dahlem St., Pittsburgh 6, Pa.
Preload Corp., 211 E. 37th St., New York 16, N. Y.

COAGULATING AIDS
Philadelphia Quartz Co., 1146 Public Ledger Bldg., Philadelphia 6, Ill.

COAL & ASH HANDLING MACHINERY
(See Ash & Coal Handling Machinery)

COATINGS, ACID & ALKALI-PROOF
Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Atlas Mineral Products Co., Mertztown, Pa.
Ebony Paint Manufacturing Co., 18th and Agnes Ave., Kansas City 1, Mo.
Hamilton Kent Mfg. Co., 218 Gougler Ave., Kent, Ohio.
Haynes Products Co., 4607 Farnam St., Omaha 3, Nebr.
Inertol Co., Inc., 480 Frelinghursen Ave., Newark 5, N. J.
Johns-Manville Corp., 22 East 40th Street, New York 16.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Philadelphia Quartz Co., 1146 Public Ledger Bldg., Philadelphia 6, Pa.

COATINGS AND LININGS
(See Bituminous Coatings and Linings)

COCKS (Cock, Meter, Corporation, Etc.)
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
Ford Meter Box Co., Wabash, Ind.
H. D. Fowler Co., Inc., 901 Lane St. (P.O. Box 3084), Seattle, Wash.
Glauber Brass, Inc., Kinsman, Ohio
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., E. Orange, N. J.

COLLECTORS (Sludge)
(See Sludge Collectors)

COMBUSTION INDICATORS AND RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Permutit Co., 330 W. 42nd St., New York 18, N.Y.

COMMINUTORS
(See Grinders also)
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.

COMPARATORS, COLOR
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
Hellige, Inc., 37-18 Northern Blvd., Long Island City, N. Y.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Wallace and Tiernan, Newark 1, New Jersey.

COMPOUNDS, SEWER JOINT
Atlas Mineral Prod. Co., Mertztown, Pa.

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
H. D. Fowler Co., Inc., 901 Lane St. (P.O. Box 3084), Seattle, Wash.
Hydraulic Development Corp., 50 Church St., New York City.
Northrop & Co., Inc., Spring Valley, N. Y.

COMPRESSORS, AIR

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Davey Compressor Co., Kent, Ohio
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
The Jaeger Machine Co., 550 W. Spring St., Columbus 16, Ohio.
Roots-Connersville Blower Corp., P. O. Box 327, Connersville, Ind.
Standard Stoker Co., Erie, Pa.
Yeomans Bros. Co., 1423 N. Dayton St., Chicago 22, Ill.

CONCRETE BREAKERS

Homelite Corp., Port Chester, N. Y.

CONCRETE HARDENER

Diamond Alkali Co., Pittsburgh.
Dow Chemical Co., Midland, Mich.
Haynes Products Co., 4097 Farnam St., Omaha 3, Nebr.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7.
Philadelphia Quartz Co., 1146 Public Ledger Bldg., Philadelphia 6, Pa.

CONCRETE MIXERS

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Jaeger Machine Co., 716 Dublin Ave., Columbus 16, Ohio.

CONCRETE PIPE

Lock-Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Preload Corp., 211 E. 37th St., New York 16, N. Y.

CONDENSERS (Steam)

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
R. D. Cole Mfg. Co., Newnan, Ga.
Westinghouse Elec. Corp., Pittsburgh 30, Pa.

CONTRACTORS (Water & Sewage Works)

Cement Gun Co., P. O. Box 424, Allentown, Pa.
Hammond Iron Works, Warren, Pa.
Layne & Bowler, Inc., Box 6818, Hollywood Sta., Memphis 8, Tennessee.
Municipal Service Co., Dept. M. 3, 908 Grand Avenue, Kansas City, Mo.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Roberts Filter Mfg. Co., Darby, Penna.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

CONTROLLERS, FLOW, LEVEL, PRESSURE, TEMPERATURE

Automatic Control Co., 1005 University Avenue, St. Paul 4, Minnesota.
B/W Controller Corp., 2206 E. Maple Rd., Birmingham, Mich.
Bailey Meter Co., 1672 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Healy-Ruff Co., 783 Hampden Ave., St. Paul, Minn.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Leupold & Stevens Inst., 4445 N. E. Glissen, Portland, Ore.
Lumenite Electronic Co., 407 So. Dearborn, Chicago, Ill.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia 44, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia, Pa.
Sperling Meter Co., Box 3277, Los Angeles 54, Calif.

CONVEYORS AND CONVEYING EQUIPMENT

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dracco Corp., 4079 E. 116th St., Cleveland 5, Ohio.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Mfg. Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Omega Machine Div., 345 Harris Ave., Providence 1, R. I.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

COPPER, BRASS, BRONZE

The American Brass Co., 25 Broadway, New York 4, New York.
Glauber Brass Inc., Kinsman, Ohio.
Hays Mfg. Co., Erie, Pa.

COPPERAS (Sulfate of Iron)

Phelps Dodge Refining Corp., 40 Wall St., New York, N. Y.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.

COPPER SULFATE

General Chemical Div., Allied Chemical & Dye Corp., 40 Rector Street, New York 6.
Phelps Dodge Refg. Corp., 40 Wall St., New York, N. Y.
Phippe & Bird, Inc., 303 S. Sixth St., Richmond, Va.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.
Tennessee Corp., 619 Grant Bldg., Atlanta, Ga.

COPPER TUBE

The American Brass Co., 25 Broadway, New York 4.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Mueller Co., Decatur 70, Ill.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 15, Kan.

CORPORATION & CURB COCKS
(See Cocks-Corporation, Curb & Meter)

CORROSION SUPPRESSION

Calgon, Inc., Hagan Bldg., 323 4th Ave., Pittsburgh, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
Electro Rust-Proofing Co., 29 W. Apple St., Dayton, Ohio.

COUPLINGS & CONNECTIONS, PIPE

James P. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Glauber Brass, Inc., Kinsman, Ohio.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.

COUPLINGS, FLEXIBLE

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Hamilton Kent Mfg. Co., 218 Gougler Ave., Kent, Ohio.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 4, Ohio.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

COVERS, HANDHOLE, MANHOLE, SAMPLING

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
The E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.
Warren Fdry. & Pipe Corp., 11 Broadway, New York, N. Y.

CULVERT CLEANERS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.

CULVERT PIPE
(See Pipe, Culvert)

CURB BOXES

Central Foundry Co., Murray & Pacific Sts., Newark, N. J.
H. W. Clark Co., Mattoon, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Verako Products, Inc., Grand Ave. & Skokie Rd., Waukegan, Wis.
Welsbach Corp., 1500 Walnut St., Philadelphia 2, Pa.

DECHLORINATING EQUIPMENT AND CHEMICALS

American Water Softener Co., Philadelphia 33, Pa.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
General Chemical Co., 40 Rector St., New York, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Wallace and Tiernan, Newark 1, New Jersey.

DE-MINERALIZATION EQUIPMENT (Water)

American Well Works, 100 N. Broadway, Aurora, Ill.
Chem. Equipment Co., P. O. Box 3098, Term. Annex, Los Angeles 54, Calif.
Dorr Co., Barry Place, Stamford, Conn.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.

DIAPHRAGM, PUMP
(See Pumps, Diaphragm)

DIATOMITE FILTER SEPTUMS

Carborundum Co., Perth Amboy, N. J.
Infilco Inc., 325 W. 25th Pl., Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Proportioneers, Inc., 345 Harris Ave., Providence, R. I.

DIESEL ENGINES
(See Engines, Diesel)

DIFFUSERS—PLATES, TUBES & FITTINGS

Carborundum Co., Perth Amboy, N. J.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Walker Process Equipment, Inc., Aurora, Ill.

DIGESTER EQUIPMENT (Sludge)

Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
Dorr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St. (P.O. Box 3084), Seattle, Wash.
Hardinge Co., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., Aurora, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

DISTRIBUTORS (Sewage Filter)

American Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Dorr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

DRAINS, GUTTER, FLOOR

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.

DRILLING & BORING EQUIPMENT

Bucyrus-Erie Co., South Milwaukee, Wis.
Hydrauger Corp., Ltd., 116 New Montgomery St., San Francisco.

DRIVES, CHAIN
(See Chains)

DRIVES, RIGHT ANGLE GEAR

De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Payne Dean Co., Madison, Conn.

DRIVES, V-BELT

Allis-Chalmers Mfg. Co., 1192 So. 70th St., Milwaukee, Wis.

DRY CHEMICAL FEEDERS
(See Chemical Feeding Equipment)

DRYING SYSTEMS (Sludge)

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
R. D. Cole Mfg., Newnan, Ga.
Combustion Engineering - Superheater, Inc., 200 Madison Ave., New York, N. Y.
Dorr Co., Barry Place, Stamford, Conn.
Gen. Amer. Transp. Co., 10 E. 40th St., New York 17, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Morse Boulger Destructor Co., 205 E. 42nd St., New York 17, N.Y.
Nichols Engineering & Research Corp., 70 Pine St., New York 5.
Posey Iron Works, Inc., Lancaster, Pa.

EARTH BORING TOOLS

Hydrauger Corp., Ltd., 681 Market St., San Francisco 5, Calif.

EARTH MOVING EQUIPMENT

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wisc.
Bucyrus-Erie Co., South Milwaukee, Wis.

EJECTORS, PNEUMATIC or STEAM (For Sewage and Sludge)

Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
H. D. Fowler Co., Inc., 901 Lane St., Seattle, Wash.
Posey Iron Works, Inc., 560 So. Prince St., Lancaster, Pa.
Westinghouse Elect. Corp., Pittsburgh 30, Pa.
Yeomans Bros. Co., 1423 N. Dayton St., Chicago 22, Ill.

ELECTRICAL CONTROL EQUIPMENT

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Automatic Control Co., 1005 University Ave., St. Paul, Minn.
B/W Controller Corp., 2206 E. Maple Rd., Birmingham, Mich.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
General Electric Corp., Schenectady, N. Y.
Healy-Ruff Co., 783 Hampden Ave., St. Paul, Minn.
Lumenite Electronic Co., 407 So. Dearborn St., Chicago, Ill.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia 44, Pa.

Sparling Meter Co., Box 3277, Los Angeles 54, Calif.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

ELECTRICAL TESTING EQUIPMENT
Simpson Electric Co., 5200 West Kinzie St., Chicago 44, Ill.

ELECTRICALLY OPERATED GATE VALVES
(See Valves, Motor Operated)

ELEVATING AND CONVEYING EQUIPMENT
(See Conveyors & Conveying Equipment)

ENGINE-GENERATOR UNIT
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Climax Engine & Pump Mfg. Co., 208 South La Salle Street, Chicago 4, Illinois.
Davey Compressor Co., Kent, Ohio
W. S. Darley & Co., 2910 Washington Blvd., Chicago 12, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Homelite Corp., Riverdale Ave., Port Chester, N. Y.
(Gasoline Engine Driven and Portable)
Westinghouse Electric Corp., Pittsburgh 30, Pa.

ENGINES, DIESEL
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.

ENGINES, DUAL FUEL
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Fairbanks, Morse & Co., 600 South Michigan Ave., Chicago 5, Ill.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.

ENGINES (Gas & Gasoline)
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Climax Engine & Pump Mfg. Co., 208 South La Salle Street, Chicago 4, Illinois.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.

ENGINES, SLUDGE GAS
Allis Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Climax Engine & Pump Mfg. Co., 208 South La Salle Street, Chicago 4, Illinois.
Fairbanks, Morse & Co., 600 South Michigan Ave., Chicago 5, Ill.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.

EXPANSION JOINTS—PIPE
(See Joints—Expansion, Pipe)

EXHAUSTERS, AIR
(See Pump, Vacuum)

FANS, EXHAUST AND VENTILATING
Dracco Corp., 4079 E. 116th St., Cleveland 5, O.
Jeffrey Mfg. Co., 906 N. 4th St., Columbus 16, Ohio.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

FEED, CHEMICAL
(See Chemical Feeding Equipment)

FEED WATER FILTERS
Chemical Equipment Co., P. O. Box 3026, Terminal Annex, Los Angeles 54, Calif.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.

FEED WATER HEATERS
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Westinghouse Elect. Corp., Pittsburgh 30, Pa.

FERRIC CHLORIDE
Dow Chemical Co., Midland, Mich.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
(Liquid)
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

FERRIC CHLORIDE FEEDERS
(See Chemical Feed and Proportioning Equipment)

FERRIC SULFATE
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
E. M. Sergeant Pulp and Chemical Co., Inc., 7 Dey St., New York 7, N. Y.
Tennessee Corp., 619 Grant Bldg., Atlanta, Ga.

FIBRE PIPE
(See Pipe, Fibre)

FILTER ALUM
Activated Alum Sales Corp., 316 Wyndhurst Ave., Baltimore 10, Md.
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector Street, New York 6, N. Y.
Penn Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

FILTER EQUIPMENT
American Well Works, 100 N. Broadway, Aurora, Ill.
R. D. Cole Mfg., Newnan, Ga.
Carborundum Co., Refractories Div., Perth Amboy, N. J.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
U. S. Hoffman Mach. Corp., 111 Fourth Ave., New York 3, N. Y.
Walker Process Equip. Co., Aurora, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

FILTER MEDIA
Anthracite Equipment Co., Wilkes-Barre, Pa.

FILTER PLATES AND TUBES
Carborundum Co., Perth Amboy, N. J.
H. D. Fowler Co., Inc., 901 Lane St. (P.O. Box 3084), Seattle, Wash.

FILTER RATE CONTROLLERS & GAGES
(See Rate Controllers.)

FILTERS, SAND & GRAVEL
Graver Water Conditioning Co., 216 West 14th Street, New York, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh, Pa.
The Permutit Co., 330 W. 42nd Street, New York 18, N. Y.

FILTER UNDERDRAINS, SEWAGE
American Well Works, 100 N. Broadway, Aurora, Ill.
Carborundum Co., Refractories Div., Perth Amboy, N. J.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.

FILTER UNDERDRAINS, WATER
Amer. Well Works, 100 N. Broadway, Aurora, Ill.
The Carborundum Co., Perth Amboy, N. J.
Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Nat'l Clay Pipe Mfrs., Inc., 100 N. LaSalle St., Chicago 2, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore, Md.
Walker Process Equipment, Inc., Aurora, Ill.

FILTERS, VACUUM
U. S. Hoffman Machinery Corp., 111 Fourth Ave., New York 3.

FILTER WASH CONTROL
Builders-Providence, Inc., 850 Harris Ave., Providence, R. I.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.

FITTINGS, PIPE, SOLDER TYPE
The American Brass Co., 25 Broadway, New York 4, New York.
Cast Iron Pipe Research Assoc., 122 S. Michigan Ave., Chicago 3, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
Hays Mfg. Co., Erie, Pa.
Johns-Manville Corp., 22 East 40th St., New York 16.
Lock Joint Pipe Co., P. O. Box 269, E. Orange, N. J.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
United States Pipe and Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 55 Liberty Street, New York 5, N. Y.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia 5, Pa.

FITTINGS, TEES, ELLS, ETC.
American Cast Iron Pipe Co., P. O. Box 2603, Birmingham 3, Ala.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Glauber Brass Inc., Kinsman, Ohio.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., Erie, Pa.
The Kennedy Valve Mfg. Co., 1036 E. Water St., Elmira, N.Y.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 55 Liberty Street, New York 5, N. Y.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia, Pa.

FLASH MIXING EQUIPMENT
(See Mixers & Mixing Equipment)

FLEXIBLE JOINTS
(See Joints, Flexible Pipe.)

FLOATING COVERS (Digester)
Ralph B. Carter, 192 Atlantic St., Hackensack, N. J.
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Walker Process Equip., Inc., Aurora, Ill.

FLOCCULATING EQUIPMENT
American Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
Dorr Co., Barry Place, Stamford, Conn.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Jeffrey Mfg. Co., 906 N. 4th St., Columbus 16, Ohio.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore, Md.
Walker Process Equip., Inc., Aurora, Ill.
Yeomans Bros. Co., 1423 N. Dayton St., Chicago 22, Ill.

FLOOR STANDS
American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve Co., Williamsport, Pa.
The Filer & Stowell Company, 147 E. Becher Street, Milwaukee 7, Wisconsin.
Infilco Inc., 325 W. 25th Pl., Chicago 16, Ill.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Lee Hydraulic Co., P. O. Box 804, Troy, N. Y.
F. B. Leopold Co., 2413 W. Carson St., Pittsburgh 4, Pa.
Mueller Co., 2501 Chestnut St., Chattanooga, Tenn.
M & H Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Rensselaer Valve Co., Troy, N. Y.
A. P. Smith Mfg. Co., 845 N. Arlington Ave., E. Orange, N. J.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia, Pa.

FLOORING, GRIDS, GRATINGS, TREADS, ETC.
Blaw-Knox Company, 2051 Farmers Bank Bldg., Pittsburgh 22, Pa.
Irving Subway Grating Co., Inc., 27th St., 49th and 51st Aves., Long Island City 1, N. Y.

FLOW METERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Bethlehem Fdry. & Machine Co., Bethlehem, Pa.
Builders - Providence, Inc., 345 Harris Ave., Providence, R. I.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.

Infilco Inc., 325 W. 25th Pl., Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Leupold & Stevens Inst., 4445 N. E. Glisan, Portland, Ore.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.

FLOW RECORDERS
(See Rate of Flow Recorders)

FLOW REGULATORS
(See Rate of Flow Controllers)

FLOW TUBES
Bethlehem Fdry. & Mach. Co., Bethlehem, Pa.
Foster Engineering Co., 835 Lehigh Avenue, Union, N. J.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco Inc., 325 W. 25th Pl., Chicago 16, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

FLUMES, IRON & STEEL
R. D. Cole Mfg. Co., Newnan, Ga.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

FLUORIDATION CHEMICALS
Blockson Chemical Co., P. O. Box 1407 Joliet, Ill.
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.

FLUORIDATION EQUIPMENT
Omega Machine Co., 345 Harris Ave., Providence, R. I.
Proportioneers Inc., 345 Harris Ave., Providence, R. I.

FOOT VALVE WITH STRAINER
(See Valves, Foot)

FORMS & GASKETS FOR PIPE JOINTS
Northrop & Co., Inc., Spring Valley, N. Y.

FURNACES, MELTING, POURING LADLES, POTS, ETC.
Atlas Mineral Products Co., Mertztown, Pa.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Hydraulic Development Corp., 50 Church St., New York City.
Lee Hydraulic Co., P. O. 804, Troy, N. Y.
Michael Hayman & Co., Inc., 870 E. Ferry St., Buffalo, N. Y.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.

GAGES (Liquid Level, Pressure Recording)
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 850 Harris Ave., Providence, R. I.
The Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Leupold & Stevens Inst., 4445 N. E. Glisan, Portland, Ore.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia, Pa.
Williams Gauge Co., 1630 Penn. Ave., Pittsburgh 12, Pa.

GARBAGE GRINDERS
(See Grinders)

GAS DIFFUSERS
Carborundum Co., Perth Amboy, N. J.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Walker Process Equip., Inc., Aurora, Ill.

GAS ENGINES
(See Engines, Gas)

GAS HOLDERS
American Well Works, 100 N. Broadway, Aurora, Ill.
Chicago Bridge & Iron Company, 332 S. Michigan Ave., Chicago.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
R. D. Cole Mfg. Co., Newnan, Ga.
The Dorr Company, Barry Place, Stamford, Conn.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25.
Posey Iron Works, Inc., Lancaster, Pa.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Walker Process Equip., Inc., Aurora, Ill.

GAS INDICATORS AND DETECTORS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Cambridge Instrument Co., Inc., 72 E. 45th St., New York, N. Y.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.

GATES, SHEAR
Chapman Valve Mfg. Co., 303 Hampshire St., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Lee Hydraulic Co., P. O. Box 804, Troy, N. Y.
Mueller Co., 2501 Chestnut St., Chattanooga, Tenn.
M & H Valve & Fittings Co., P. O. Box 909, Anniston, Ala.

GATES, SLUICE
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Chapman Valve Mfg. Co., 303 Hampshire St., Indian Orchard, Mass.
R. D. Cole Mfg., Newnan, Ga.
The Filer & Stowell Co., 147 E. Bocher Street, Milwaukee 7, Wis.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Lee Hydraulic Co., P. O. Box 804, Troy, N. Y.
Mueller Co., 2501 Chestnut St., Chattanooga, Tenn.
R-S Products Corp., 4600 Germantown Ave., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.

GATE VALVE OPERATOR
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve and Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Lee Hydraulic Co., P. O. Box 804, Troy, N. Y.
Payne Dean & Co., Madison, Conn.
A. P. Smith Mfg. Co., E. Orange, N. J.

GATE VALVES
(See Valves, Gate)

GEARS, SPEED REDUCING
Allis-Chalmers Mfg. Co., 1102 S. 70th St., Milwaukee, Wis.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Westinghouse Elec. Corp., Pittsburgh 30, Pa.

GEIGER COUNTERS
Beckman Instruments, Inc., 820 Mission St., South Pasadena, Calif.
The Detectron Co., 5631 Cahuenga Blvd., North Hollywood, Calif.
The Goldak Co., 1544 W. Glenoaks Blvd., Glendale 1, Calif.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

GENERATORS
Allis-Chalmers Mfg. Co., 1102 S. 70th St., Milwaukee, Wis.
Fairbanks, Morse & Co., 600 South Michigan Ave., Chicago 5, Ill.
General Electric Co., Schenectady, N. Y.
Homelite Corp., Riverdale Ave., Port Chester, N. Y.
Westinghouse Elec. Corp., Pittsburgh 30, Pa.

GENERATOR SETS, GAS & DIESEL ENGINES
(See Engine Generating Units)

GOOSENECKS
Albert Pipe Supply, Berry and N. 13th St., Brooklyn, N. Y.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80.
Glauber Brass, Inc., Kinsman, Ohio
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., E. Orange, N. J.

GRATINGS (See Flooring)

GREEN SAND (See Zeolite)
Amer. Water Softener Co., Philadelphia 32, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
Graver Water Conditioning Co., 216 West 14th Street, New York, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N.Y.
Roberts Filter Mfg. Co., Darby, Pa.
Zeolite Chemical Co., 140 Cedar, New York 6, N. Y.

GRINDERS, GARBAGE & SCREENINGS
Amer. Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Ill.
Dorr Co., Barry Place, Stamford, Conn.
General Electric Co. (household), Bridgeport, Conn.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Walker Process Equipment, Inc., Aurora, Ill.
Westinghouse Elect. Corp. (household), Pittsburgh, Pa.

GRIT CHAMBER EQUIPMENT & GRIT WASHERS
American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Ill.
Dorr Co., Barry Place, Stamford, Conn.
Infilco Inc., 325 W. 25th Place, Chicago 16, Ill.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Walker Process Equip., Inc., Aurora, Ill.

GROUND KEY STOPS
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
The Ford Meter Box Co., Inc., Wabash, Ind.
Glauber Brass, Inc., Kinsman, Ohio
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., E. Orange, N. J.
The Welsbach Corp., Kitson Division, 1500 Walnut Street, Philadelphia 2, Pa.

GUNITING CONTRACTING
Cement Gun Company, Inc., 1520 Walnut Street, Allentown, Pa.

HEATERS, DIGESTER
American Radiator & Standard Sanitary Corp., Box 1226, Pittsburgh 30, Pa.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Ill.
Dorr Co., Barry Place, Stamford, Conn.
Infilco Inc., 325 W. 25th Pl., Chicago 16, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Walker Process Equip., Inc., Aurora, Ill.

HOSE, STEAM, AIR, WATER, SUCTION
The American Brass Co., 25 Broadway, New York 4, N. Y.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.

HYDRANT PUMPS
(See Pumps, Hydrant)

HYDRANTS (Fire)
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Darling Valve Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
The Kennedy Valve Mfg. Co., 1036 E. Water St., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., 2501 Chestnut St., Chattanooga, Tenn.
Rensselaer Valve Co., Ontario Street, Troy, N. Y.
Ross Valve Mfg. Co., Inc., Box 836, Troy, N. Y.
A. P. Smith Mfg. Co., E. Orange, N. J.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 13, Kan.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia, Pa.

HYDRAULICALLY OPERATED GATE VALVES
(See Valves, Gate)

HYDROGEN ION EQUIPMENT
(See pH Test Equipment)

HYPO-CHLORINATORS
Chemical Equipment Co., P. O. Box 5099, Terminal Annex, Los Angeles 54, Calif.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Omega Machine Co., 345 Harris Ave., Providence 1, R. I.
Precision Machine Co., 9 Union Square, Sommerville, Mass.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Wallace and Tiernan, Newark 1, N. J.

HYPOCHLORITES (High Test)
(See Calcium Hypochlorite)

INCINERATORS
Combustion Engineering - Superheater, Inc., 200 Madison Ave., New York, N. Y.
Dorr Co., Barry Place, Stamford, Conn.

Morse Boulger Destructor Co., 305 E. 42nd St., New York 17, N.Y.
Nichols Engineering & Research Corp., 70 Pine St., New York 5, N. Y.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25, Pa.

INDICATORS, LARGE DIAL, ILLUMINATED

Automatic Control Co., 1005 University Ave., St. Paul, Minn.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Leupold & Stevens Inst., 4445 N. E. Glisan, Portland, Ore.
M & H Valve & Fittings Co., P. O. Box 949, Anniston, Ala.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.

INSECTICIDES

General Chemical Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.

INSERTING SLEEVES, VALVE

Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Lee Hydraulic Co., P. O. Box 804, Troy, N. Y.
A. P. Smith, 545 N. Arlington Ave., East Orange, N. J.

INSTRUMENTS (Meteorological)

Leupold & Stevens Inst., 4445 N. E. Glisson, Portland, Ore.
Payne Dean and Co., Madison, Conn.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Wallace and Tiernan, Newark 1, N. J.

INSULATION

Johns-Manville, 22 E. 40th St., New York City.
National Gypsum Co., Buffalo, N. Y.

IRON SULFATE

(See Ferric Sulfate, or Ferrous Sulfate)

JOINTING COMPOUND AND MATERIALS

Atlas Mineral Prod. Co., Mertztown, Pa.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
Ebony Paint Mfg. Co., 18th & Agnes Ave., Kansas City 1, Mo.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Michael Hayman & Co., 870 E. Ferry St., Buffalo, N. Y.
Hydraulic Development Corp., 50 Church St., New York City.
Johns-Manville Corp., 22 East 40th Street, New York 16, N. Y.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.
Leadlite Co., Philadelphia, Pa.
Northrop & Co., Inc., Spring Valley, N. Y.
Warren Foundry & Pipe Corp., 55 Liberty Street, New York 5, N. Y.

JOINTS, EXPANSION—PIPE

James B. Clow, 201-299 N. Talman Ave., Chicago 80, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Hamilton Kent Mfg. Co., 218 Gougler Ave., Kent, Ohio.
Johns-Manville Corp., 22 E. 40th Street, New York 16, N. Y.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Warren Foundry & Pipe Corp., 55 Liberty St., New York 5, N. Y.

JOINTS, FLEXIBLE PIPE

Hamilton Kent Mfg. Co., 218 Gougler Ave., Kent, Ohio.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
United States Pipe and Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 55 Liberty Street, New York 5, N. Y.

JOINTS, MECHANICAL, FLEXIBLE

Amer. Brass Co., Waterbury, Conn.
Carson-Cadillac Corp., 1221 Pinson St., Birmingham, Ala.
Central Foundry Co., Murray & Pacific Sts., Newark, N. J.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
The A. P. Smith Mfg. Co., East Orange, New Jersey.
United States Pipe and Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.

JUTE, BRAIDED AND TWISTED

Atlas Mineral Prod. Co., Mertztown, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hydraulic Development Corp., 50 Church St., New York City.
Michael Hayman & Co., Inc., 870 E. Ferry St., Buffalo, N. Y.
Northrop & Co., Inc., Spring Valley, N. Y.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.

LABORATORY APPARATUS, REAGENTS AND EQUIPMENT

Cambridge Instrument Co., Inc., 72 E. 45th St., New York, N. Y.
Central Scientific Co., 1700 Irving Park Rd., Chicago 13, Ill.
Coleman Instruments, Inc., 318 Madison St., Maywood, Ill.
Calgon, Inc., 323 4th Ave., Hazan Bldg., Pittsburgh, Pa.
Fisher Research Laboratory, Inc., 1961 University Ave., Palo Alto, Calif.
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector Street, New York 6, N. Y.
Heiltge, Inc., 8738 Northern Blvd., Long Island City, N. Y.
Klett Mfg. Co., 179 E. 87th St., New York 28, N. Y.
Nat'l Technical Labs., Los Angeles, Calif.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.

LEAD, CAULKING

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Sonken-Galamba Corp., 2nd and Riverview, Kansas City 18, Kan.

LEAK LOCATING INSTRUMENTS

(See Water Leak Locating Instruments)

LIGHTING

General Electric Co., Schenectady, N. Y.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

LIMES, HYDRATED & QUICK

Dow Chemical Co., Midland, Mich.
National Gypsum Co., 325 Delaware Ave., Buffalo 2, N. Y.

LIQUID CHLORINE

(See Chlorine, Liquid)

LOCATORS, BOX, PIPE AND VALVE

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
The Detectron Co., 5431 Cahuenga Blvd., North Hollywood, Calif.
Fischer Research Lab., Inc., 1961 University Ave., Palo Alto, Calif.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
The Goldak Co., 1544 W. Glenoaks Blvd., Glendale 1, Calif.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.
E. H. Wachs Co., 1825 Dayton St., Chicago 22, Ill.

LUBRICANTS, VALVE

American Car and Foundry Co., Valve Div., 1501 Ferry Avenue East, Detroit, Mich.

MANHOLE FRAMES, COVERS

H. W. Clark Co., Mattoon, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
R. D. Cole Mfg., Newnan, Ga.
The E. H. Wachs Co., 1825 Dayton St., Chicago 22, Ill.
Warren Foundry & Pipe Corp., 55 Liberty St., New York 5, N. Y.

MANOMETERS

Builders - Providence, Inc., 350 Harris Ave., Providence 1, R. I.
Fischer & Porter Company, Dept. 9F, Hatboro, Pa.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Norwalk Valve Co., 33 Railroad Ave., South Norwalk, Conn.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Wallace and Tiernan, Newark 1, N. J.

METER ACCESSORIES, BOXES, HOUSING SETTING, ETC.

Art Concrete Works, Pasadena, Calif.
H. W. Clark Co., Mattoon, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Darling Valve & Manufacturing Co., Williamsport, Pa.
Ford Meter Box Co., Wabash, Ind.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
Iowa Valve Co., Oskaloosa, Iowa.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., E. Orange, N. J.

METER COUPLINGS & YOKES

Badger Meter Mfg. Co., 2371 North 30th St., Milwaukee, Wis.
H. W. Clark Co., Mattoon, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Ford Meter Box Co., Wabash, Ind.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Glauber Brass, Inc., Kinsman, Ohio
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Mueller Co., Decatur 70, Ill.
Neptune Meter Co., 50 West 50th St., New York City.
Welsbach Corp., 1500 Walnut St., Philadelphia 2, Pa.

METER REPAIR PARTS

Badger Meter Mfg. Co., 2371 North 30th St., Milwaukee, Wis.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Meter Specialty Co., Sterick Bldg., Memphis, Tenn.
Neptune Meter Co., 50 West 50th St., New York 20, N. Y.
Rockwell Manufacturing Co., Pittsburgh Equitable Meter Division, 400 N. Lexington Ave., Pittsburgh 8, Pa.

METERS, ELECTRIC

General Electric Co., Schenectady, N. Y.
Infilco Inc., 325 W. 25th Pl., Chicago 16, Ill.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Simpson Electric Co., 5200 W. Kinzie St., Chicago 44, Ill.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

METERS, FLOW TUBE

Bethlehem Fdry. & Mach. Co., Bethlehem, Pa.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.

METERS, GAS

Bailey Meter Company, 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Cambridge Instrument Co., Inc., 72 E. 45th St., New York, N. Y.
Fischer & Porter Co., Hatboro, Pa.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Rockwell Manufacturing Co., Pittsburgh Equitable Meter Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Roots-Connersville Blower Corp., P. O. Box 327, Connersville, Ind.

METERS, HYDRAULIC TURBINES

The Foxboro Co., Neponset Ave., Foxboro, Mass.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

METER TESTING EQUIPMENT

Badger Meter Mfg. Co., 2371 North 30th St., Milwaukee, Wis.
Fischer & Porter Co., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Ford Meter Box Co., Wabash, Ind.
Neptune Meter Co., 50 W. 50th St., New York City.
Simpson Electric Co., 5200 W. Kinzie St., Chicago 44, Ill.
Worthington-Gamon Meter Co., Newark, N. J.

METERS, VENTURI

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Bethlehem Fdry. & Machine Co., Bethlehem, Pa.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

METERS, WATER & SEWAGE

Badger Meter Mfg. Co., 2371 North 30th St., Milwaukee, Wis.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Bethlehem Fdry. & Machine Co., Bethlehem, Pa.
Buffalo Meter Co., 2209 Main St., Buffalo, N. Y.
Builders-Providence, Inc., 350 Harris Ave., Providence 1, R. I.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco Inc., 325 W. 25th Pl., Chicago 16, Ill.
Leupold & Stevens Instruments, Inc., 4445 N. E. Glisan St., Portland 13, Oregon.
Neptune Meter Co., 50 West 50th St., New York 20, N. Y.
Rockwell Manufacturing Co., Pittsburgh Equitable Meter Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.
Worthington-Gamon Meter Co., Newark, N. J.

METERS, CLEANING SOLUTION

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, O.
Builders - Providence, Inc., 156 Harris Ave., Providence 1, R. I.
Infilco Inc., 325 W. 25th Pl., Chicago 16, Ill.
Neptune Meter Co., 50 West 50th Street, New York 20, New York.

MIXERS AND MIXING EQUIPMENT

(Chemical, Water and Sewage)

American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., Barry Place, Stamford, Conn.
Infilco, Inc., 325 W. 25th Pl. Chicago 16, Ill.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., 2413 W. Carson St., Pittsburgh 4, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equipment, Inc., Aurora, Ill.

MOTORS, ELECTRIC

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
General Electric Co., Schenectady, N. Y.
Sonken-Galamba Corp., 2nd and Riverview, Kansas City 18, Kansas.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

NIPPLES, PIPE

A. M. Byers Co., Pittsburgh, Pa.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Dresser Mfg. Co. Div., Bradford, Pa.
Glauber Brass, Inc., Kinsman, Ohio
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Sonken-Galamba Corp., 2nd and Riverview, Kansas City 18, Kan.

NO-OX-ID

Dearborn Chem. Co., 310 S. Michigan Ave., Chicago, Ill.

NOZZLES, FLOW

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco Inc., 325 W. 25th Pl., Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

NOZZLES, SPRAY

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Infilco Inc., 325 W. 25th Pl., Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Yeomans Bros. Co., 1423 N. Dayton St., Chicago 22, Ill.

OPERATING TABLES (Filter)

Amer. Water Softener Co., Philadelphia 32, Pa.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., 518 Hanken Ave., Aurora, Ill.

ORIFICES

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

OZONE EQUIPMENT

The Welsbach Corp., Ozone Processes Div., 1500 Walnut St., Philadelphia 2, Pa.

PACKING

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Johns-Manville, 22 E. 40th St. New York City.
Northrop & Co., Inc., Spring Valley, N. Y.

PAINT, ACID RESISTING

Atlas Mineral Prod. Co., Mertztown, Pa.
Ebony Paint Manufacturing Co., 18th and Agnes Ave., Kansas City 1, Mo.
Haynes Products Co., 4007 Farnam St., Omaha 3, Nebr.
Inertol Co., Newark 5, N. J.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

PENSTOCKS

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wisc.
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Hammond Iron Works, Warren, Pa.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25, Pa.
Posey Iron Works, Inc., Lancaster, Pa.
Santa Fe Tank & Tower Co., 5401 S. Boyle Ave., Los Angeles 58, Calif.

pH TEST EQUIPMENT

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Beckman Instruments, Inc., 820 Mission St., So. Pasadena, Calif.
Cambridge Instrument Co., Inc., 72 E. 45th St., New York, N. Y.
Coleman Instruments, Inc., 318 Madison St., Maywood, Ill.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Hellige, Inc., 37-18 Northern Blvd., Long Island City, N. Y.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
The Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
W. A. Taylor & Co., 7360 York Rd., Baltimore, Md.
Wallace & Tiernan, Newark 1, N. J.

PHOTOELECTRIC COLORIMETERS

Beckman Instruments, Inc., 820 Mission St., South Pasadena, Calif.
Central Scientific Co., 1700 Irving Park Road, Chicago 13, Ill.
Hellige, Inc., 37-18 Northern Blvd., Long Island City, N. Y.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

PIPE & FITTINGS, SARAN, ETC.

Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Carter Products Corp., Bedford, Ohio
Sonken-Galamba Corp., 2nd and Riverview, Kansas City 18, Kan.

PIPE AND TANK COATINGS

Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Dearborn Chem. Co., 310 S. Michigan Ave., Chicago, Ill.
Ebony Paint Manufacturing Co., 18th and Agnes Ave., Kansas City 1, Mo.
Johns-Manville Corp., 22 East 40th Street, New York 16, N. Y.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

PIPE, ASBESTOS-CEMENT

Johns-Manville Co., 22 E. 40th St., New York City.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Keasbey & Mattison Co., Ambler, Pa.

PIPE BENDING MACHINES

H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hays Mfg. Co., Erie, Pa.
Jos. G. Pollard Co., Inc., 141 S. Ashland Pl., Brooklyn 1, N.Y.

PIPE, CAST IRON

American Cast Iron Pipe Co., P. O. Box 2603, Birmingham 3, Ala.
Cast Iron Pipe Research Assoc., 122 S. Michigan Ave., Chicago 3, Ill.
Central Foundry Co., Murray and Pacific St., Newark, N. J.
James B. Clow & Sons, 201-299 No. Talman Ave., Chicago 12, Ill.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
McWane Cast Iron Pipe Co., P.O. Box 2601, Birmingham, Ala.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Southwestern Lumber Co., 7457 South Western Ave., Chicago 36, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 55 Liberty St., New York 5, N. Y.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia, Pa.

PIPE, CEMENT LINED

American Cast Iron Pipe Co., P. O. Box 2603, Birmingham 3, Ala.
Cast Iron Pipe Research Assoc., 122 S. Michigan Ave., Chicago 3, Ill.
Central Foundry Co., Murray and Pacific Sts., Newark, N. J.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Posey Iron Works, Inc., Lancaster, Pa.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 55 Liberty St., New York 5, N. Y.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia 5, Pa.

PIPE, CEMENT LINING OF

Centriline Corp., 140 Cedar St., New York City.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
United States Pipe and Foundry Co., Burlington, N. J.

PIPE, CONCRETE, PRESSURE

Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Preload Corp., 211 E. 37th St., New York 16, N. Y.

PIPE, COPPER, BRASS AND BRONZE

The American Brass Co., 25 Broadway, New York 4, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

PIPE, CULVERT

Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, New York.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Nat'l Clay Pipe Mfrs., Inc., 100 N. LaSalle St., Chicago, Ill.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
United States Pipe and Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 55 Liberty St., New York 5, N. Y.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia, Pa.

PIPE CUTTING MACHINES

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Lee Hydraulic Co., P. O. Box 804, Troy, N. Y.
Jos. G. Pollard Co., Inc., New Hyde Park, N. Y.
Ridge Tool Co., Elyria, Ohio.
The A. P. Smith Mfg. Co., East Orange, N. J.
E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.

PIPE DRILLS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Jos. G. Pollard Co., Inc., 141 Ashland Pl., Brooklyn 1, N.Y.
The A. P. Smith Mfg. Co., East Orange, N. J.

PIPE ENAMELS, PROTECTIVE—COAL TAR

Ebony Paint Mfg. Co., 18th & Agnes Ave., Kansas City 1, Mo.
Inertol Co., Newark 5, N. J.

PIPE FITTINGS (See Fittings)

PIPE, HARD RUBBER LINED

American Hard Rubber Co., 11 Mercer St., New York 13, N.Y.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 54, Calif.

PIPE JOINT COMPOUNDS
(See Jointing Compounds.)

PIPE JOINTS (Mechanical)

Carson-Cadillac Corp., 1221 Pinson St., Birmingham, Ala.
Cast Iron Pipe Research Assoc., 122 S. Michigan Ave., Chicago 3, Ill.
Central Foundry Co., 286 Murray and Pacific Sts., Newark, N. J.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
United States Pipe and Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia 5, Pa.

PIPE JOINT PACKING, STERILE

Hydraulic Development Corp., 50 Church St., New York, N. Y.

PIPE JOINT TOOLS

Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.

Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., Decatur 70, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.

PIPE LOCATORS
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
The Detectron Co., 5631 Cahuenga Blvd., North Hollywood, Calif.
Fisher Research Lab., 1961 University Ave., Palo Alto, Calif.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3064, Seattle Wash.
Globe Phone Mfg. Corp., 2 Linden St., Reading, Mass.
The Goldak Co., 1544 W. Glenoaks Blvd., Glendale 1, Calif.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.

PIPE, PLASTIC
Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Carlon Products Corp., 10225 Meech Ave., Cleveland, Ohio.
Lee Hydraulic Co., P. O. Box 804, Troy, N. Y.

PIPE, SEWER
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Kennedy & Mattison Co., Ambler, Pa.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Nat'l Clay Pipe Mfrs., 100 N. La Salle St., Chicago, Ill.
Preload Corp., 211 E. 37th St., New York 16, New York.
U. S. Pipe & Foundry Co., Burlington, N. J.

PIPE, STEEL (All Types)
R. D. Cole Mfg. Co., Newnan, Ga.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Posey Iron Works, Inc., Lancaster, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

PIPE TAPPING MACHINES
Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., E. Orange, N. J.
The E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.

PIPE TEST PLUGS
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 18, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Flexible Sewer Rod Equip. Co., 9069 Venice Blvd., Los Angeles, Calif.
Richmond Fdry. & Mfg. Co., P. O. Box 5150, Saunders Sta., Richmond, Va.
A. P. Smith Mfg. Co., E. Orange, N. J.

PIPE THAWING, ELECTRICAL, STEAM, FLAME
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.

PIPE TOOLS,
(Asbestos, Cement)
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3064), Seattle, Wash.
Kennedy & Mattison Co., Ambler, Pa.
Pilot Manufacturing Co., 420 Market St., San Francisco 11, Calif.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.

PIPE TOOLS (Cutters, Extractors, Threaders, Wrenches, Etc.)
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3064, Seattle, Wash.
Johns-Manville Corp., 22 East 40th Street, New York 16, N. Y.
Marlow Pumps, Ridgewood, N. J.
Pilot Manufacturing Co., 420 Market St., San Francisco 11, Calif.
Ridge Tool Co., 400 Clark St., Elyria, Ohio.
Trimont Mfg. Co., Div. of Aetna Industrial Corp., 55-71 Armory St., Roxbury 19, (Boston), Mass.

PIPE, VITRIFIED CLAY
(See Vitrified Clay Pipe and Products.)

PIPE WRAPPING
Johns-Manville Corp., 22 East 40th St., New York 16, N. Y.

PIPE, WROUGHT IRON
A. M. Byers Co., Clark Bldg., Pittsburgh, Pa.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Grinnell Co., Inc., 260 N. Exchange St., Providence 1, R. I.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Posey Iron Works, Inc., Lancaster, Pa.
Sonken-Galamba, 2nd & Riverview, Kansas City 18, Kan.

PITOT TUBES
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Leupold & Stevens Inst., 4445 N.E. Glisson, Portland, Ore.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

PNEUMATIC CONVEYORS FOR WATER AND SEWAGE TREATMENT
Dracco Corp., 4079 E. 116th St., Cleveland 5, Ohio.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

POROUS TUBES AND PLATES
Carborundum Co., Perth Amboy, N. J.
Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

POWER TAKE-OFFS
(Truck Type)
Davey Compressor Co., Kent, Ohio
Payne Dean Co., Madison, Conn.

PRESTRESSED CONCRETE TANKS
Cement Gun Co., Inc., 1520 Walnut St., Allentown, Pa.
Preload Corp., 211 E. 37th St., New York 16, N. Y.

PRESSURE REGULATORS
(See Regulators, Pressure)

PROPORTIONING EQUIPMENT
(See Chemical Feed and Proportioning Equip.)

PUMPING CONTROLS
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Automatic Control Co., 1005 University Ave., St. Paul 4, Minn.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, O.
Barrett-Haentjens & Co., Hazleton, Pa.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
B/W Controller Corp., 2206 E. Maple Rd., Birmingham, Mich.
Chicago Pump Company, 2300 Wolfram St., Chicago 18, Ill.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, O.
Foster Engineering Co., 925 Le-High Avenue, Union, N. J.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Healy-Ruff Co., 733 Hampden Ave., St. Paul, Minn.
Lumenite Electronic Co., 407 S. Dearborn St., Chicago 5, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMP PRIMERS
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Barrett-Haentjens & Co., Hazleton, Pa.
Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Marlow Pumps, Ridgewood, N. J.
Milton Roy Co., 1329 E. Mermaid Lane, Philadelphia 18, Pa.
Valve and Primer Corp., 127 N. Dearborn St., Chicago 2, Ill.

PUMPS, ACID-HANDLING
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Milton Roy Co., 1329 Mermaid Lane, Philadelphia 18, Pa.
Peerless Pump Div. Food Machinery and Chemical Corp., 301 W. Ave. 26, Los Angeles 31, Calif.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMPS, CELLAR DRAINER
(See Pumps, Sump)

PUMPS, CENTRIFUGAL
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St., Milwaukee, Wis.
Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3064, Seattle, Wash.
Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.
Homelite Corp., Port Chester, N. Y.
Jaeger Machine Co., 716 Dublin Ave., Columbus 16, O.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Marlow Pumps, Ridgewood, N. J.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Yeomans Brothers Co., 1423 Dayton St., Chicago 22, Ill.

PUMPS, DEEP WELL
American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Layne & Bowler, Inc., Box 6818, Hollywood Sta., Memphis 8, Tenn.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

PUMPS, DIAPHRAGM
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Chemical Equipment Co., P. O. Box 3095, Terminal Annex, Los Angeles 12, Calif.
Domestic Engine & Pump Co., Shippensburg, Pa.
Dorr Co., Barry Place, Stamford, Conn.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco Inc., 325 W. 25th Pl., Chicago 16, Ill.
The Jaeger Machine Co., 550 W. Spring St., Columbus 16, Ohio.
Marlow Pumps, Inc., Ridgewood, N. J.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Yeomans Brothers Co., 1423 Dayton St., Chicago 22, Ill.

PUMPS, DRAINAGE (See Pumps, Sewage and Drainage)

PUMPS, HIGH PRESSURE FOR TRUCK MOUNTING
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Fairbanks, Morse & Co., 600 South Michigan Ave., Chicago 5, Ill.
Marlow Pumps, Ridgewood, N. J.

PUMPS, HYDRANT
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.

PUMPS, HYDRAULIC
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
Ross Valve Mfg. Co., Inc., P. O. Box 896, Troy, N. Y.

PUMPS, JETTING
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Domestic Engine & Pump Co., Shippensburg, Pa.
Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.
The Jaeger Machine Co., 550 W. Spring St., Columbus 16, Ohio.
Marlow Pumps, Ridgewood, N. J.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Iowa.

PUMPS, PORTABLE
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St., Milwauke 4, Wis.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Domestic Engine & Pump Co., Shippensburg, Pa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Homelite Corp., Port Chester, N. Y.
The Jaeger Machine Co., 550 W. Spring St., Columbus 16, Ohio.
Marlow Pumps, Ridgewood, N. J.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMPS, ROTARY
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Ill.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Roots-Connersville Blower Corp., P. O. Box 327, Connersville, Ind.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

PUMPS, SELF PRIMING
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
Fairbanks, Morse & Co., 400 South Michigan Ave., Chicago 5, Ill.
Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.
Homelite Corp., Port Chester, N. Y.
The Jaeger Machine Co., 550 W. Spring St., Columbus 16, Ohio.
Layne & Bowler, Inc., P. O. Box 215 Hollywood Sta., Memphis 8, Tenn.
Marlow Pumps, Ridgewood, N. J.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMPS, SEWAGE AND DRAINAGE

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
The Dorr Co., Barry Place, Stamford, Conn.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.
Homelite Corp., Port Chester, N. Y.
The Jaeger Machine Co., 550 W. Spring St., Columbus 16, Ohio.
Marlow Pumps, Ridgewood, N. J.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
S. Morgan Smith Co., York, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kansas.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMPS, SLUDGE

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Barrett-Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
DeLaval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
Dorr Co., Garry Place, Stamford, Conn.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Marlow Pumps, Ridgewood, N. J.
Peerless Pump Div., Food Machinery & Chemical Corp., 301 W. Ave. 26, Los Angeles 31, Calif.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Walker Process Equip, Inc., 515 Hankee Ave., Aurora, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMPS, SUMP (AND CELLAR DRAINER)

American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
De Laval Steam Turbine Co., Trenton 2, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.
Homelite Corporation, Port Chester, New York.
Jaeger Machine Co., 716 Dublin Ave., Columbus 16, O.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26, Los Angeles, Calif.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMPS, TURBINE

American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Layne & Bowler, Inc., Box 6818, Hollywood Sta., Memphis 8, Tennessee.
Peerless Pump Div., Food Machinery Corp., 301 West Avenue 26, Los Angeles 31, Calif.
R-S Products Corp., 4000 Germantown Ave., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMPS, VACUUM

Allen-Billmyre Div., Lamson Corp., Syracuse 1, N. Y.
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Barrett, Haentjens & Co., Hazleton, Pa.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton 2, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
Dracco Corp., 4079 E. 116th St., Cleveland 5, O.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Roots-Connersville Blower Corp., P O. Box 327, Connersville, Ind.
U. S. Hoffman Mach. Corp., 111 Fourth Ave., New York 3, N. Y.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

RAIN GAGES

Leupold & Stevens Instruments, Inc., 4445 N. E. Glisan St., Portland 13, Oregon.
Lumenite Electronic Co., 407 S. Dearborn St., Chicago 5, Ill.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
M. C. Stewart, Ashburnham, Mass.

RATE OF FLOW CONTROLLERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Badger Meter Mfg. Co., 2371 North 30th St., Milwaukee, Wis.
Builders-Providence, Inc., 850 Harris Ave., Providence, R. I.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
Fisher & Porter Company, Dept. 9F, Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Healy-Ruff Co., 782 Hampden Ave., St. Paul, 4, Minnesota.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Pittsburgh Equitable Meter Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.

RATE OF FLOW RECORDERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 850 Harris Ave., Providence, R. I.
Cambridge Instrument Co., Inc., 72 E. 45th St., New York, N. Y.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St. (P.O. Box 3084), Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Leupold & Stevens Inst., 4445 N. E. Glissen, Portland, Ore.
Lumenite Electronic Co., 407 S. Dearborn St., Chicago 5, Ill.
Pittsburgh Equitable Meter Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
S. Morgan Smith Co., York, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.

REAMERS

Mueller Co., Decatur 70, Ill.
Ridge Tool Co., Elyria, Ohio.

RECARBONATORS

(See Carbonators)

REFRACTORIES

Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.

REGULATORS, PRESSURE (Water and Gas)

American Radiator Co., Benesmer Bldg., Pittsburgh, Pa.
Automatic Control Co., 1005 University Ave., St. Paul, Minn.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Foster Engineering Co., 835 Le-High Avenue, Union, N. J.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Spec., Co., 1329 Fulton Bldg., Pittsburgh.
Healy-Ruff Co., 783 Hampden Ave., St. Paul 4, Minnesota.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia 44, Pa.
Mueller Co., Decatur 70, Ill.
Norwalk Valve Co., 33 Railroad Ave., South Norwalk, Conn.
Rockwell Manufacturing Co., Pittsburgh Equitable Meter Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Ross Valve Mfg. Co., P. O. Box 995, Troy, N. Y.
S. Morgan Smith Co., York, Pa.
The Williams Gauge Co., 1630 Penna. Ave., Pittsburgh 32, Pa.

RESIDUAL CHLORINE CONTROL APPARATUS

Chemical Equipment Co., P. O. Box 3095, Term. Annex, Los Angeles 54, Calif.
Hellige, Inc., 37-18 Northern Blvd., Long Island City, N. Y.
LaMotte Chem. Co., Towson 4, Md.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
Wallace and Tiernan, Newark 1, New Jersey.

ROOF COATINGS

Haynes Products Co., 4007 Farnam St., Omaha 3, Nebr.
Johns-Manville Corp., 22 East 40th St., New York 16, New York.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.

RUBBER LINED PIPE AND VALVES

American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Chem. Equip. Co., P. O. Box 3095 Term. Annex, Los Angeles 54, Calif.
Darling Valve & Mfg. Co., Williamsport, Pa.

RUBBER PACKING GASKETS

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Johns-Manville Corp., 22 East 40th St., New York 16, New York.
Northrop & Co., Spring Valley, N. Y.

RUST PREVENTION (Tanks, Pipe Lines, Submerged Metal)

Calgon, Inc., Hagan Bldg., 323 4th Ave., Pittsburgh, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
Ebony Paint Mfg. Co., 18th and Agnes Ave., Kansas City 1, Mo.
Electro Rust-Proofing Corp., (N. J.), Belleville, N. J.
Dearborn Chem. Co., 310 S. Michigan Ave., Chicago, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.
Philadelphia Quartz Co., 1146 Public Ledger Bldg., Philadelphia 6, Pa.

SADDLES, PIPE

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Brandford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

SAMPLERS AND SAMPLING TABLES

Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
Hardinge Co., Inc., 240 Arch St., York, Pa.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

SAND EXPANSION INDICATORS

Builders-Providence, Inc., 850 Harris Ave., Providence, R. I.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

SCALES, SLUDGE CONVEYOR

Builders-Providence, Inc., 850 Harris Ave., Providence 1, R. I.
Fairbanks, Morse & Co., 600 South Michigan Ave., Chicago 5, Ill.
Nichols Engineering & Research Corp., 70 Pine St., New York 5, N. Y.

SCALES, WEIGHING

Fairbanks-Morse Co., 600 S. Michigan Ave., Chicago 5, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Nichols Engineering & Research Corp., 70 Pine St., New York 5, N. Y.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 8, Va.
Wallace & Tiernan, Belleville 9, N. J.

SCREENINGS, DEWATERERS

Gen. Amer. Trans. Corp., 10 E. 40th St., New York 17, N. Y.

SCREENINGS GRINDERS

(See Grinders)

SCREENS, INTAKE

Amer. Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

SCREENS, SEWAGE

American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
Dorr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St. (P.O. Box 3084), Seattle, Wash.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Walker Process Equip. Co., Aurora, Ill.

SCREENS, VIBRATING

Allis-Chalmers Mfg. Co., 1192 S 70th St., Milwaukee 1, Wis.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

SCREENS, WATER WELL

Layne & Bowler, Inc., Box 6818, Hollywood Sta., Memphis 8, Tennessee.

SCUM REMOVERS

(See Clarifiers.)

SEGMENT BLOCKS AND PIPE LINER PLATES (Vitrified)

Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Nat'l Clay Pipe Mfrs. Inc., 100 N. LaSalle St., Chicago 2, Ill.

SEPTIC TANK CLEANERS

Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.

SEPTIC TANKS (Vitrified Clay)

Nat'l Clay Pipe Mfrs., Inc., 100 N. LaSalle St., Chicago 2, Ill.

SERVICE BOXES

Central Foundry Co., Murray & Pacific Sts., Newark, N. J.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N.J.

SERVICE PIPE

The American Brass Co., 25 Broadway, New York 4, New York.
Glauber Brass Inc., Kinsman, Ohio.
Johns-Manville Corp., 22 East 40th Street, New York 16, New York.

SEWAGE EJECTORS

(See Ejectors, Pneumatic.)

SEWAGE SAMPLERS

Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.

SEWAGE SLUDGE DRYERS

(See Drying Systems, Sludge)

SEWAGE SLUDGE INCINERATOR

(See Incinerators)

SEWAGE TREATMENT PROCESSES

The Bio-Chemical Process, 2266 N. Meridian St., Indianapolis, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.

SEWER CLEANING EQUIP. AND SERVICE

Bucyrus-Erie Co., South Milwaukee, Wis.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Expanding Sewer Machine Co., 108 E. Walnut St., Nappanee, Ind.
J. C. Fitzgerald, P.O. Box 299, Coral Gables 34, Fla.
Flexible Sewer-Rod Equt. Co., 9059 Venice Blvd., Los Angeles, Calif.
H. D. Fowler Co., Inc., 901 Lane St. (P.O. Box 3084), Seattle, Wash.
Phelps Dodge Refining Corp., 40 Wall St., New York 5, N.Y.
Pittsburgh Pipe Cleaner Co., 133 Dahlem St., Pittsburgh 6, Pa.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

SEWER PIPE

(See Pipe, Sewer.)

SEWER PIPE JOINTS

Atlas Mineral Prod. Co., Mertztown, Pa.
H. D. Fowler Co., Inc., 901 Lane St. (P.O. Box 3084), Seattle, Wash.
Hydraulic Development Corp., 50 Church St., New York City.
National Clay Pipe Manufacturers, Inc., 100 North LaSalle St., Chicago 2, Illinois.
Northrop & Company, Inc., Spring Valley, N.Y.
L. A. Weston Co., 2 Dean St., (P.O. Box 6), Adams, Mass.

SEWER RODS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Expanding Sewer Machine Co., 108 E. Walnut St., Nappanee, Ind.
Flexible Sewer-Rod Equt. Co., 9059 Venice Blvd., Los Angeles, Calif.
Joseph G. Pollards Co., Inc., New Hyde Park, N.Y.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

SIPHONS (Sewage)

American Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N.J.
H. D. Fowler Co., Inc., 901 Lane St. (P.O. Box 3084), Seattle, Wash.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.

SLEEVES, PIPE REPAIR

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Eddy Valve Co., Waterford, N.Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Lee Hydraulic Co., P. O. Box 804, Troy, N. Y.
Mueller Co., 2501 Chestnut St., Chattanooga, Tenn.
Rensselaer Valve Co., Ontario Street, Troy, New York.
A. P. Smith Mfg. Co., East Orange, N. J.
Warren Foundry & Pipe Corp., 55 Liberty Street, New York 5, N. Y.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

SLEEVES, TAPPING (Valve)

Eddy Valve Co., Waterford, N.Y.
Darling Valve & Manufacturing Co., Williamsport, Penna.
Dresser Manufacturing Div., 32 Fisher Ave., Bradford, Pa.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Mueller Co., 2501 Chestnut St., Chattanooga, Tenn.
M. & H. Valve & Fittings Co., P.O. Box 909, Anniston, Ala.
Rensselaer Valve Co., Ontario Street, Troy, New York.
A. P. Smith Mfg. Co., East Orange, N. J.

SLUDGE COLLECTORS

American Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
Dorr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St., P.O. Box 3084, Seattle, Wash.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Walker Process Equip., Inc., Aurora, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

SLUDGE DISINTEGRATORS

Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Royer Foundry & Mach. Co., 158 Pringle St., Kingston, Pa.

SLUDGE EJECTORS

(See Ejectors, Pneumatic.)

SLUDGE ELEVATORS, LIQUID

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Hardinge Corp., York, Pa.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, O.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Walker Process Equip., Inc., Aurora, Ill.

SLUDGE GAS ENGINES

(See Engines, Sludge Gas)

SLUDGE PUMPS

(See Pumps, Sludge)

SLUDGE SAMPLERS

Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Chicago Pump Co., 2249 Wolfram St., Chicago 18, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va

SNUBBERS

(See Silencers.)

SODA ASH

Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
Diamond Alkali Co., 300 Union Commerce Bldg., Cleveland 14, Ohio.
Mathieson Chemical Corp., Mathieson Bldg., Baltimore 3, Maryland.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Pittsburgh Plate Glass Co., Columbia Chemical Div., Fifth Ave. at Bellefield, Pittsburgh 13, Pa.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.
Solvay Sales Div., Allied Chemical & Dye Corporation, 40 Rector Street, New York 6, New York.

SODIUM BISULPHITE

General Chemical Div., Allied Chemical & Dye Corp., 40 Rector Street, New York 6, N. Y.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

SODIUM CHLORITE

Mathieson Chemical Corp., Mathieson Bldg., Baltimore 3, Maryland.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

SODIUM PHOSPHATES (Glassy)

Blockson Chemical Co., P.O. Box 1497, Joliet, Illinois.
Calgon, Inc., Hagan Bldg., 323 Fourth Ave., Pittsburgh 30, Pa.
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector Street, New York 6, N. Y.

SODIUM SILICATE

Diamond Alkali Co., 300 Union Commerce Bldg., Cleveland 14, Ohio.
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector Street, New York 6, N. Y.
Philadelphia Quartz Co., 1146 Public Ledger Bldg., Philadelphia 6, Pa.

SOFTENERS

(See Water Softening Equipment)

SPEED REDUCERS, TRANSMISSION

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

SPRINKLING FILTER EQUIP.

American Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter, 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St. (P.O. Box 3084), Seattle, Wash.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Walker Process Equip., Inc., Aurora, Ill.
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

SPRINKLING FILTER UNDERDRAINS

(See Filter Underdrains, Sewage.)

STACKS

Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Hammond Iron Works, 630 Fifth Ave., New York, N. Y.
Posey Iron Works, Inc., Lancaster, Pa.

STANDPIPES

(See Tanks and Standpipes.)

STANDPIPE AND TANK PRESERVATION

(See Cathodic Protection Process.)

STERILIZING WATER MAINS

(See Water Main Sterilization)

STIRRERS (Laboratory)

Omega Machine Co., 345 Harris Avenue, Providence 1, Rhode Island.
Phipps & Bird, Inc., 303 S. 6th St., Richmond, Va.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

STOKERS

Combustion Engineering - Superheater, Inc., 200 Madison Ave., New York, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Link-Belt Co., 2410 W. 18th St., Chicago 8, Ill.
Westinghouse Electric & Mfg. Co., Pittsburgh 30, Pa.

STORAGE TANKS
(See Standpipes and Tanks)

STRAINERS, SUCTION
Barrett, Haentjens & Co., Hazleton, Pa.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
R.-S. Products Corp., 4600 Germantown Ave., Philadelphia, Pa.

SULPHATE OF ALUMINA
(See Filter Alum)

SULPHUR DIOXIDE (Liquid)
Tennessee Corp., 619 Grant Bldg., Atlanta, Ga.

SUPERNATANT LIQUOR
(Handling and Treatment)
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
Pacific Flush-Tank Co., 4141 Ravenswood Ave., Chicago 13, Ill.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Walker Process Equip, Inc., 518 Hanlon Ave., Aurora, Ill.

SWITCHBOARD & SWITCH GEAR
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
B/W Controller Corp., 2206 E. Maple Rd., Birmingham, Mich.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio.
General Electric Co., Schenectady, N. Y.
Westinghouse Electric Mfg. Co., Pittsburgh 30, Pa.

TANK MAINTENANCE & REPAIR
Cement Gun Co., Inc., 1520 Walnut Street, Allentown, Penna.
Dixie Tank & Bridge Co., P. O. Box 14, Memphis 1, Tenn.
R. D. Cole Mfg. Co., Newnan, Ga.
Hammond Iron Works, 630 Fifth Ave., New York, N. Y.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Specimen Elevated Tank Service, 822 N. Court St., Rockford, Ill.

TANKS & PIPES, WOOD
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Santa Fe Tank & Tower Co., 5401 S. Boyle Ave., Los Angeles 58, Calif.

TANKS AND STANDPIPES, ELEVATED (Steel)
Amer. Car and Foundry Co., 30 Church St., New York 8, N. Y.
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Hammond Iron Works, 630 Fifth Ave., New York, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
General American Process Equipment Div., 420 Lexington Ave., New York 17, N. Y.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25, Pa.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Posey Iron Works, Inc., Lancaster, Pa.
Santa Fe Tank & Tower Co., 5401 S. Boyle Ave., Los Angeles 58, Calif.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 12, Kan.

TANKS, RUBBER LINED
Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Atlas Mineral Products Co., Mertztown, Pa.
R. D. Cole Mfg. Co., Newnan, Ga.
Hammond Iron Works, Warren, Pa.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Posey Iron Works, Inc., Lancaster, Pa.
Proportioneers, Inc., 945 Harris Ave., Providence 1, R. I.

TAPPING MACHINES
Glauber Brass, Inc., Kinsman, Ohio.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., East Orange, N. J.
E. H. Wachs Co., 1825 Dayton St., Chicago 22, Ill.

TASTE & ODOR REMOVAL CHEMICALS
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., Inc., 230 Park Ave., New York 17, N. Y.
Mathieson Chem. Corp., 60 E. 42nd St., New York 17, N. Y.
Phelps Dodge Refg. Corp., 40 Wall St., New York, N. Y.
Welsbach Corp., Ozone etc. Ozone Processes Division, 1500 Walnut Street, Philadelphia 2, Pa.

TESTERS (Water Meter)
Ford Meter Box Co., Wabash, Ind.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Neptune Meter Co., 50 W. 50th St., New York City.
Worthington-Gamon Meter Co., Newark, N. J.

TEST PLUGS (for Pipe)
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Eddy Valve Co., Waterford, N. Y.
Flexible Sewer Rod Equip. Co., 9059 Venice Blvd., Los Angeles, Calif.
Glauber Brass, Inc., Kinsman, Ohio.
Richmond Fdry. & Mfg. Co., P.O. Box 5150, Saunders Sta., Richmond, Va.
A. P. Smith Mfg. Co., E. Orange, N. J.

THICKENERS (Sludge)
Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Dorr Co., Barry Place, Stamford, Conn.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Walker Process Equip., Inc., Aurora, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

TOOL BOXES, PORTABLE
Littleford Bros., Inc., 453 E. Pearl St., Cincinnati 21, Ohio.

TOOLS, PIPE
(See Pipe Tools.)

TOOLS, PNEUMATIC
Jaeger Machine Co., 716 Dublin Ave., Columbus, Ohio.
Lee Hydraulic Co., P.O. Box 804, Troy, N. Y.

TRACTORS, BULLDOZERS, Etc.
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wisc.
Bucyrus-Erie Co., South Milwaukee, Wis.

TRANSFORMERS, ELECTRIC
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
General Electric Co., Schenectady, N. Y.
Westinghouse Electric Corp., Pittsburgh, Pa.

TRAPS, DRIP, FLAME, SEDIMENT, STEAM
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
H. D. Fowler Co., Inc., 901 Lane St. (P.O. Box 3084), Seattle, Wash.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Josam Mfg. Co., 1302 Ontario St., Cleveland 13, Ohio.
Neptune Meter Co., 50 W. 50th St., New York 20, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
The Williams Gauge Co., 1620 Pennsylvania Ave., Pittsburgh 33, Pa.

TRENCHING EQUIPMENT
Bucyrus-Erie Co., South Milwaukee, Wis.
Hydrauger Corp., Ltd., 116 New Montgomery St., San Francisco, Calif.

TRICKLING FILTER EQUIPMENT
American Well Wks., 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St. (P.O. Box 3084), Seattle, Wash.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Avenue, Chicago 13, Illinois.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Walker Process Equipment, Inc., Aurora, Ill.
Yeomans Bros., 1423 N. Dayton St., Chicago 22, Ill.

TRICKLING FILTER UNDERDRAINS
(See Filter Underdrains)

TRITURATORS
(See also Grinders)
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.

TUNNEL LINER PLATES
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.

TURBIDIMETERS
Hellige, Inc., 87-18 Northern Blvd., Long Island City 1, N.Y.
Klett Mfg. Co., 179 E. 87th St., New York 28, N. Y.
Phipps & Bird, Inc., 300 S. 6th St., Richmond 5, Va.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.

TURBINES, HYDRAULIC
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
De Laval Steam Turbine Co., Trenton, N. J.
R-S Products Corp., 4600 Germantown Ave., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.

TURBINES, STEAM
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Westinghouse Elect. Corp., Pittsburgh 30, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.

UNIT SUBSTATIONS
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
General Electric Co., Schenectady, N. Y.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

VACUUM FILTERS
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
U. S. Hoffman Machinery Corp., 111 Fourth Ave., New York 3, N. Y.

VALVE BOXES
Central Foundry Co., Murray & Pacific Sts., Newark, N. J.
Chapman Valve Mfg., Indian Orchard, Mass.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Darling Valve & Manufacturing Co., Williamsport, Penna.
Eddy Valve Co., Waterford, N. Y.
Ford Meter Box Co., Wabash, Ind.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
H. W. Clark Co., Mattoon, Ill.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., E. Orange, N. J.
Veraks Products, Inc., Grand Ave. & Skokie Rd., Waukegan, Wis.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia, Pa.

VALVE BOX LOCATORS
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
The Detectron Co., 5631 Cahuenga Blvd., North Hollywood, Calif.
Globe Phone Mfg. Co., 2 Linden St., Reading, Mass.
The Goldak Co., 1544 W. Glenoaks Blvd., Glendale 1, Calif.

VALVE INSERTING MACHINES
A. P. Smith Mfg. Co., E. Orange, N. J.

VALVE OPERATOR
(See Gate Valve Operator)

VALVES, AIR RELEASE (See Air Release Valves)

VALVES, AIR RELEASE & VACUUM BREAKING
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve & Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
H. D. Fowler Co., Inc. 901 Lane St., P. O. Box 3084, Seattle, Wash.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Norwalk Valve Co., 33 Railroad Avenue, South Norwalk, Conn.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Rockwell Mfg. Co., Nordstrom Valve Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Rensselaer Valve Co., Ontario Street, Troy, New York.
Simplex Valve & Meter Co., 6748 Upland St., Philadelphia 42, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Valve and Primer Corp., 127 N. Dearborn St., Chicago, Ill.
Williams Gauge Co., 1620 Pennsylvania Ave., Pittsburgh 33, Pa.

VALVES, ALTITUDE
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Foster Engineering Co., 835 Le-High Avenue, Union, N. J.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Specialty Co., 207 Keenan Bldg., Pittsburgh 22, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, BACKWATER
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Co., Keenan Bldg., Pittsburgh 22, Pa.
The Kennedy Valve Mfg. Co., 1656 E. Water St., Elmira, N. Y.

VALVES, BUTTERFLY
Crane Co., 836 S. Mich. Ave., Chicago 5, Ill.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P.O. Box 3084, Seattle, Wash.

Foxboro Co., Neponset Ave., Foxboro, Mass.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith Co., York, Pa.

VALVES, CHECK

Amer. Car and Foundry Co., 30 Church St., New York 8, N. Y.
Barrett, Haentjens & Co., Hazleton, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
Foster Engineering Co., 835 Le-High Avenue, Union, N. J.
H. D. Fowler Co., Inc., 901 Lane St. (P.O. Box 3084), Seattle, Wash.
Golden-Anderson Valve Specialty Co., 207 Keenan Bldg., Pittsburgh 22, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus 46, Ohio.
The Kennedy Valve Mfg. Co., 1036 E. Water St., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., P.O. Box 909, Anniston, Ala.
Mueller Co., 2501 Chestnut St., Chattanooga, Tenn.
Northrop & Co., Inc., Spring Valley, N. Y.
Norwalk Valve Co., 33 Railroad Ave., South Norwalk, Conn.
Rensselaer Valve Co., Ontario Street, Troy, New York.
A. P. Smith Mfg. Co., E. Orange, N. J.
S. Morgan Smith Co., York, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kansas.
Williams Gauge Co., 1620 Penn Ave., Pittsburgh 12, Pa.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

VALVES, CHLORINE

Amer. Car and Fdy. Co., 30 Church St., New York 8, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Wallace and Tiernan, Newark 1, New Jersey.

VALVES, (Compression)

Glauber Brass, Inc., Kinsman, Ohio

VALVES, CONE

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
S. Morgan Smith Co., York, Pa.
R-S Products Corp., 4600 Germantown Ave., Philadelphia, Pa.

VALVES, DIAPHRAGM

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Fischer & Porter Co., Hatboro, Pa.
Foster Engineering Company, 835 LeHigh Avenue, Union, New Jersey.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Grinnell Co., Inc., 240 W. Exchange St., Providence 1, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Norwalk Valve Co., 33 Railroad Ave., South Norwalk, Conn.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.

VALVES, ELECTRICALLY OPERATED

(See Valves, Motor Operated.)

VALVES, EMERGENCY TRIP

Golden-Anderson Valve Spec. Co., 207 Keenan Building, Pittsburgh 22, Pa.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.

VALVES, FLAP

Chapman Valve Mfg. Co., Indian Orchard, Mass.
The Filer & Stowell Co., 147 E. Becher Street, Milwaukee 7, Wisconsin.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., P.O. Box 909, Anniston, Ala.
Mueller Co., 2501 Chestnut St., Chattanooga, Tenn.
Norwalk Valve Co., 33 Railroad Ave., South Norwalk, Conn.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.

VALVES, FLOAT

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Foster Engineering Co., 835 Le-High Avenue, Union, New Jersey.
Golden-Anderson Valve Specialty Co., 207 Keenan Building, Pittsburgh 22, Pa.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith Co., York, Pa.

VALVES, FOOT

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Eddy Valve Co., Waterford, N. Y.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
The Williams Gauge Co., 1620 Penn. Ave., Pittsburgh 12, Pa.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

VALVES, FOUR WAY

American Water Softener Co., Philadelphia 33, Pa.
American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
F. E. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Rockwell Manufacturing Co., Nordstrom Valve Div., 400 N. Lexington Ave, Pittsburgh 8, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
The E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.

VALVES, GATE

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Darling Valve Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
The Filer & Stowell Co., 147 E. Becher Street, Milwaukee 7, Wisconsin.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
The Kennedy Valve Mfg. Co., 1036 E. Water St., Elmira, N. Y.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., 2501 Chestnut St., Chattanooga, Tenn.
Rensselaer Valve Co., Ontario Street, Troy, New York.
A. P. Smith Mfg. Co., E. Orange, N. J.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia, Pa.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.

VALVES, HARD RUBBER LINED

American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve & Manufacturing Co., Williamsport, Penna.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
R-S Products Corp., 4600 Germantown Ave., Philadelphia, Pa.

VALVES, HYDRAULIC CYLINDER OPERATED

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve & Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
H. D. Fowler Co., Inc., 901 Lane St. (P.O. Box 3084), Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Specialty Co., 207 Keenan Building, Pittsburgh 22, Pa.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
The Kennedy Valve Mfg. Co., 1036 E. Water St., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Rensselaer Valve Company, Ontario Street, Troy, New York.
Rockwell Manufacturing Co., Nordstrom Valve Division, 400 N. Lexington Ave., Pittsburgh 8, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
A. P. Smith Mfg. Co., East Orange, N. J.
S. Morgan Smith Co., York, Pa.

VALVES, LUBRICATED PLUG

American Car and Foundry Co., Valve Division, 1501 Ferry Avenue East, Detroit, Michigan.
Rockwell Manufacturing Co., Nordstrom Valve Division, 400 N. Lexington Ave., Pittsburgh 8, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

VALVES MECHANICAL JOINT

Eddy Valve Co., Waterford, N. Y.

VALVES, MOTOR OPERATED

Chapman Valve Mfg. Co., Indian Orchard, Mass.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve & Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
The Filer & Stowell Co., 147 E. Becher Street, Milwaukee 7, Wisconsin.
H. D. Fowler Co. Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Specialty Co., 207 Keenan Building, Pittsburgh 22, Pa.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
The Kennedy Valve Mfg. Co., 1036 E. Water St., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., P.O. Box 909, Anniston, Alabama.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia 44, Pa.
Mueller Co., 2501 Chestnut St., Chattanooga, Tenn.
Payne Dean and Co., Madison, Conn.
Rensselaer Valve Co., Ontario Street, Troy, New York.
Rockwell Manufacturing Co., Nordstrom Valve Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
A. P. Smith Mfg. Co., East Orange, N. J.
S. Morgan Smith Co., York, Pa.

VALVES, MUD AND PLUG

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
The Filer & Stowell Co., 147 E. Becher Street, Milwaukee 7, Wisconsin.
Infilco Inc., 325 W. 25th Pl. Chicago 16, Ill.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., 2501 Chestnut St., Chattanooga, Tenn.
Roberts Filter Mfg. Co., Darby, Pa.

VALVES, PRESSURE REDUCING

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Foster Engineering Co., 835 Le-High Avenue, Union, New Jersey.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Specialty Co., 207 Keenan Building, Pittsburgh 22, Pa.
Lee Hydraulic Co., P.O. Box 804, Troy, N. Y.
Mueller Co., Decatur 70, Ill.
Norwalk Valve Co., 33 Railroad Avenue, South Norwalk, Conn.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith, York, Pa.

VALVES, RELIEF

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Foster Engineering Co., 835 Le-High Avenue, Union, New Jersey.
Cohen-Anderson Valve Specialty Co., 207 Keenan Bldg., Pittsburgh 22, Pa.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Mueller Co., Decatur 70, Ill.
Neptune Meter Co., 50 West 50th St., N. Y. 20.
Norwalk Valve Co., 33 Railroad Ave., South Norwalk, Conn.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kansas.
The Welsbach Corp., Kitson Division, 1500 Walnut Street, Philadelphia 2, Pa.

VALVES, RUBBER, GLASS AND LEAD LINED

American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Darling Valve & Mfg. Co., Williamsport, Penna.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith, York, Pa.

VALVES, SPECIAL, AUTOMATIC (Including Remote Control)

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Barrett, Haentjens & Co., Hazleton, Pa.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
Foster Engineering Co., 835 Le-High Avenue, Union, New Jersey.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Specialty Co., 207 Keenan Bldg., Pittsburgh 22, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Iowa Valve Co., 201299 N. Talman Ave., Chicago 80, Ill.
The Kennedy Valve Mfg. Co., 1936 E. Water St., Elmira, N. Y.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Rensselaer Valve Co., Ontario Street, Troy, New York.
Rockwell Manufacturing Co., Nordstrom Valve Division, 400 N. Lexington Ave., Pittsburgh 8, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith Co., York, Pa.
A. P. Smith Mfg. Co., 595 N. Arlington Ave., E. Orange, N. J.

VALVES, WATER METER SPECIAL

Ford Meter Box Co., Wabash, Ind.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.

VARIABLE SPEED TRANSMISSIONS

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

VENTURI TUBES

American Water Softener Co., Philadelphia 33, Pa.
Bailey Meter Co., 1072 Ivanhoe, Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

VIBRATING SCREENS (Liquid)

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Link Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

VISES, PIPE

H. D. Fowler Co., Inc., 901 Lane St. (P.O. Box 3084), Seattle, Wash.
The Ridge Tool Co., 400 Clark Street, Elyria, Ohio.
Trimont Mfg. Co., Div. of Aetna Industrial Corp., 55-71 Armory St., Roxbury 19, (Boston), Mass.

VITRIFIED CLAY PIPE AND PRODUCTS

Nat'l Clay Pipe Mfrs., Inc., 100 N. La Salle St., Chicago 2, Ill.

WASTE GAS BURNERS

H. D. Fowler Co., Inc., 901 Lane St. (P.O. Box 3084), Seattle, Wash.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.

WATER ANALYSIS EQUIPMENT AND REAGENTS

(See Laboratory Apparatus and Reagent.)

WATER HAMMER ARRESTERS

H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Peiton Water Wheel Co., 18th and Alabama Sts., San Francisco 10, Calif.
Ross Valve Mfg. Co., Box 595, Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith Co., York, Pa.

WATER LEAK LOCATING INSTRUMENTS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
The Detectron Co., 5631 Cahuenga Blvd., North Hollywood, Calif.
Fisher Research Lab. Inc., 1961 University Ave., Palo Alto, Calif.
H. D. Fowler Co. Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Globe Phone Mfg. Corp., 2 Linden St., Reading, Mass.
The Goldak Co., 1544 W. Glenoaks Blvd., Glendale 1, Calif.
Joseph H. Pollard Co., Inc., New Hyde Park, N. Y.

WATER LEVEL CONTROL

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wisc.
Automatic Control Corp., 1005 University Ave., St. Paul 4, Minn.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence 1, R. I.
B/W Controller Corp., 2206 E. Maple Rd., Birmingham, Mich.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
Foster Engineering Co., 835 Le-High Avenue, Union, New Jersey.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Healy-Ruff Co., 783 Hampden Ave., St. Paul, Minn.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Lumenite Electronic Co., 407 S. Dearborn St., Chicago 5, Ill.
Leupold & Stevens Instruments, Inc., 4445 N. E. Glisan St., Portland 13, Oregon.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.

WATER LEVEL RECORDERS

Automatic Control Co., 1005 University Ave., St. Paul 4, Minn.
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wisc.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders - Providence, Inc., 350 Harris Ave., Providence 1, R. I.
Fisher Research Laboratory, Inc., 1961 University Ave., Palo Alto, Calif.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Leupold & Stevens Instruments, Inc., 4445 N. E. Glisan St., Portland 13, Oregon.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

WATER MAIN CLEANING

Flexible Underground Pipe Cleaning Co., 9059 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 50 Church St., New York 7, N. Y.
Pittsburgh Pipe Cleaner Co., 133 Dahlem St., Pittsburgh 6, Pa.
Preload Corp., 211 E. 57th St., New York 16, N. Y.

WATER MAIN PACKING GASKETS

Johns-Manville Corp., 22 East 40th Street., New York 16, New York.
Northrop & Co., Spring Valley, N. Y.

WATERPROOFING PAINTS, COMPOUNDS AND MATERIALS

Ebony Paint Mfg. Co., 18th and Agnes Ave., Kansas City 1, Mo.
Haynes Products Co., 4007 Farnam St., Omaha 3, Nebr.
Inertol Co., Newark 5, N. Y.
Johns-Manville, 22 E. 40th St., New York City.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Stuart Corp., 516 N. Charles St., Baltimore, Md.

WATER SOFTENING CHEMICALS AND COMPOUNDS

(See Individual Chemicals for Water Purification and Softening)

WATER SOFTENING EQUIPMENT

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
American Well Works, 100 N. Broadway, Aurora, Ill.
Blockson Chemical Co., P.O. Box 1407, Joliet, Illinois.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 54, Calif.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
Dorr Co., Inc., Barry Place, Stamford, Conn.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2412 W. Carson St., Pittsburgh 4, Pa.
Mathieson Chemical Corp., Mathieson Bld., Baltimore 3, Maryland.
Milton Roy Co., 1329 E. Mermaid Lane, Philadelphia 18, Pa.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Roberts Filter Mfg. Co., Darby, Pa.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

WATER SUPPLY CONTRACTORS

(See Contractors)

WATER TREATMENT FOR SCALE AND CORROSION

Amer. Water Softener Co., Philadelphia 33, Pa.
Calgon, Inc., 323 4th Ave., Hagan Bldg., Pittsburgh 30, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector Street, New York 6, N. Y.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25, Pa.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.

WEED KILLERS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Dow Chemical Co., Midland, Mich.
General Chemical Division, Allied Chemical & Dye Corp., 40 Rector Street, New York 6, N. Y.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Phelps Dodge Refining Corp., 40 Wall St., New York 5, N. Y.

WELLS, COMPLETE

Layne & Bowler, Inc., Box 6818, Hollywood Sta., Memphis 8, Tennessee.

WRAPPING, PIPE

(See Pipe, Wrapping)

WRENCHES, REVERSIBLE RATCHET

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FLUORIDIZERS Available in two models (gravimetric and grooved disc types). Cannot "flood" or overfeed.

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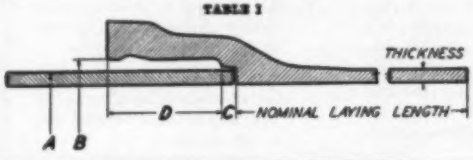
Super deLavaud Pipe with B&S Joints

Super-deLavaud Pipe with bell and spigot joints is available in all sizes from 3" to 24" and in 12-foot and 18-foot lengths. The joint is particularly adaptable for lead, cement, joint compound or rubber ring assembly. The centering ring insures easy alignment and uniform distribution of the jointing material. The process by which this pipe is produced assures concentricity, evenness of metal and freedom from sand or slag inclusions. The bell and spigot joint, made with lead or other jointing materials, shows ample strength to resist pulling apart. If required to meet service conditions, pipe will be furnished with special linings. All Super-de Lavaud Pipe with bell and spigot joints are made to meet Federal Specification WW-P-421. Write for descriptive booklet.

TABLE I



Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length 12-Foot Length: Weight of Pipe Pounds	12-Foot Length: Weight Per Foot Including Bell	18-Foot Length: Weight of Pipe Pounds	18-Foot Length: Weight Per Foot Including Bell
3	150	.33	150	12.7	225	12.4
3	250	.36	165	13.7	240	13.4
4	150	.34	195	16.4	285	15.9
4	250	.38	220	18.4	325	17.9
6	150	.37	315	26.3	480	25.5
6	250	.43	350	29.3	515	28.5
8	150	.41	475	39.4	690	38.3
8	200	.46	510	42.4	745	41.3
8	250	.50	545	45.5	800	44.3
10	150	.47	640	53.3	935	51.8
10	200	.53	700	58.3	1025	56.8
10	250	.57	760	63.3	1115	61.9
12	150	.50	810	67.4	1190	65.9
12	200	.57	905	75.4	1325	73.7
12	250	.62	990	82.5	1450	80.7

Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length 12-Foot Length: Weight of Pipe Pounds	12-Foot Length: Weight Per Foot Including Bell	18-Foot Length: Weight of Pipe Pounds	18-Foot Length: Weight Per Foot Including Bell
14	100	.48	920	76.5	1340	74.3
14	150	.55	1060	88.5	1555	86.3
14	200	.62	1190	99.0	1735	96.3
14	250	.69	1320	110.0	1930	107.2
16	100	.52	1130	94.2	1645	91.4
16	150	.60	1320	110.2	1935	107.4
16	200	.68	1495	124.1	2175	120.7
16	250	.76	1635	136.1	2390	132.7
18	100	.55	1365	113.8	1990	110.6
18	150	.63	1595	132.8	2330	129.4
18	200	.74	1810	150.9	2645	146.9
18	250	.83	2015	168.0	2950	163.9
20	100	.58	1585	132.0	2305	128.0
20	150	.68	1860	154.9	2720	151.1
20	200	.78	2125	177.1	3105	172.4
20	250	.88	2385	197.1	3465	192.4
24	100	.64	2018	172.8	3035	168.6
24	150	.78	2460	209.8	3630	201.6
24	200	.98	2854	237.8	4179	231.6
24	250	1.00	3290	268.8	4890	280.8

Threaded Cast Iron Pipe Centrifugally Cast

Super-deLavaud Cast Iron Pipe is now being manufactured in "iron pipe sizes" with threaded joints to meet the demand for a better and more durable pipe. There are two distinct types of service for which Super-deLavaud Cast Iron Pipe may be used: pressure service for water, gas, steam or similar liquids and gases; and drainage service. Pressure pipe is made to meet the requirements of Federal Specifications WW-P-421 and is supplied in three classes: standard, extra-strong and double-extra-strong. Drainage pipe, used for waste, vent and drain work, is a lighter pipe for use in buildings and elsewhere where a tight screw-coupled joint is needed. Drainage pipe is made to meet the requirements of Federal Specifications WW-P-356.

THREADED CAST IRON PRESSURE PIPE

(Made to meet the requirements of Federal Specifications WW-P-421)

Size Inches	Class	Nominal Length, Feet	Outside Diameter, Inches	Nominal Thickness Inches	Threads per Inch	Weight per foot Pounds
¼	Standard	12	0.50	.06	27	0.84
	X-strong	12	0.50	.45	18	1.45
	XX-strong	12	0.50	.65	14	1.71
⅜	Standard	12	0.68	.06	18	1.24
	X-strong	12	0.68	.42	18	1.94
	XX-strong	12	0.68	.62	14	2.39
½	Standard	12	0.84	.07	14	1.65
	X-strong	12	0.84	.46	14	2.55
	XX-strong	12	0.84	.65	14	3.19
¾	Standard	12	1.05	.07	14	2.12
	X-strong	12	1.05	.47	14	3.24
	XX-strong	12	1.05	.68	14	4.19
1	Standard	12	1.32	.08	11½	3.12
	X-strong	12	1.32	.50	11½	4.64
	XX-strong	12	1.32	.72	11½	5.85
1¼	Standard	12	1.66	.08	11½	4.00
	X-strong	12	1.66	.50	11½	6.04
	XX-strong	12	1.66	.73	11½	8.13
1½	Standard	12	1.90	.09	11½	4.86
	X-strong	12	1.90	.51	11½	7.05
	XX-strong	12	1.90	.75	11½	9.41
2	Standard	12	2.38	.09	11½	6.49
	X-strong	12	2.38	.55	11½	9.68
	XX-strong	12	2.38	.80	11½	13.09
2½	Standard	12	2.88	.12	8	9.11
	X-strong	12	2.88	.64	8	13.69
	XX-strong	12	2.88	.93	8	17.66
3	Standard	12	3.50	.12	8	11.08
	X-strong	12	3.50	.45	8	13.45
	XX-strong	12	3.50	.65	8	14.21
4	Standard	18	4.50	.26	8	15.34
	X-strong	18	4.50	.49	8	18.91
	XX-strong	18	4.50	.52	8	20.29
5	Standard	18	5.56	.40	8	20.22
	X-strong	18	5.56	.49	8	24.40
	XX-strong	18	5.56	.53	8	26.15
6	Standard	18	6.63	.43	8	28.15
	X-strong	18	6.63	.51	8	30.59
	XX-strong	18	6.63	.55	8	32.74
8	Standard	18	8.63	.50	8	39.85
	X-strong	18	8.63	.56	8	44.39
	XX-strong	18	8.63	.60	8	47.32

THREADED CAST IRON DRAIN PIPE

For Waste, Vent and Drainage Service

(Made to meet the requirements of Federal Specifications WW-P-356)

Size Inches	Nominal Length Feet	Outside Diameter Inches	Minimum Thickness Inches	Threads per Inch	Weight per Foot Pounds
2	12	2.50	.28	8	9.41
4	18	4.50	.39	8	13.75
5	18	5.56	.33	8	19.00
6	18	6.62	.33	8	26.22
8	18	8.62	.44	8	39.82

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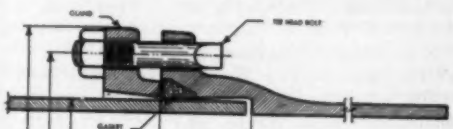

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DEVELOPING WATER RATES

Some Basic Considerations

By L. E. AYERS
Consulting Engr., Ann Arbor, Mich.
(Chairman AWWA Committee on Water Rate Schedules)

THIS paper presents the *tentative* conclusions of the author, as chairman of the Committee on Water Rates, on certain basic considerations involved in determining water rates, as outlined to the committee on March 14, 1949, presented to the Association in a panel discussion [1] at the 1949 Annual Conference and subsequently commented on in letters from committee members to the chairman.

These basic problems have been listed [1] as follows:

1. How much revenue should a water works receive?
2. In what proportions should this gross revenue be collected: (a) from property assessments and (b) through utility rates?
3. Should utility rates incorporate a "demand" or "ready-to-serve" charge; and, if so, upon what logical basis should the amount of such a charge be fixed?
4. If a "demand" charge is to be used, upon what basis should it be distributed to customers?
5. Finally, how many steps are desirable in the commodity rate; and what are the logical rules for fixing the step quantity limitations and the unit rate for each step?

Amount of Revenue Needed

Public and Private Ownership

Should there be a difference in the approach to the subject of revenue as between privately owned and publicly owned water works? It was originally the author's thought that there was a difference and that the committee discussions would be concerned largely with publicly owned properties. It was premised that all privately owned, but only a relatively few publicly owned, plants are subject to the rulings of courts and commissions; and that the A.S.C.E.-sponsored Joint Committee on Fundamental Considerations in Rates and Rate Structures for Water and Sewage Works would survey and compile the pertinent information on court and commission decisions.

It has developed however, that certain committee members believe the approach to the subject should be the same whether a water works is privately or publicly owned. As one committee member put it, the only essential difference is in the rate of return on the used property. He proposed "for interest, if a private company, from 5 to 7 per cent, dependent upon location and cost of money"; and "for interest, if a publicly owned system, from 2 to 4 per cent, which includes the interest on outstanding bonds, if any."

There is much precedent for the assumption that there should be no difference between a privately and publicly owned water works as regards the amount of return which should be received. The Wisconsin Public Service Commission is required by statute to adopt the basic principle that: "A municipally operated water utility is *entitled to the same rate of return* as that permitted for privately owned utilities"[2].

Allen Hazen [3] took the position many years ago that "the revenue produced must be sufficient to pay all operating expenses of every description, including the general administration, and this includes, in the case of works owned by cities, a proportionate part of the general expenses of the city government and of the city buildings, a fair allowance for depreciation on all property used, all taxes of every kind, and in addition, a return on the value of the plant at the rate at which money can be borrowed for the enterprise." And he goes on to declare that such a basis "if systematically followed, will result in constantly increasing surplus revenue, and ultimately part of the surplus should be dedicated to other nonproductive public purposes, such as supplying libraries, hospitals and parks."

Although there may be no illustrations of the use of water works surplus for the financing of "libraries, hospitals and parks," it is a fairly common practice for water works moneys to be turned over to the general fund of the city. In the A.W.W.A. tabulation of water works data for 1945 [4], about 170 cities of a total of 462—37 per cent—contributed to the general fund in varying amounts in 1945. Some of these cities turned over all of their receipts. Others turned over net earnings less debt requirements and, sometimes, less payments to a reserve. In addition, about an equal number, although not the same cities, gave free service. Some cities reported no allowance for depreciation, while one had a depreciation charge equal to 16.5 per cent of book value. Many paid no taxes and received no compensation for fire protection.

From other, unpublished, reports, the author notes that 7 of 36 of the nation's largest cities paid all "excess revenue over expense" to the general fund, and one city paid a "dividend on stock owned by the city."

A review of available data presents a confusing picture of the financial affairs of many municipally owned water works. From spot inspection of the record, it appears that the return on book value varies widely, ranging from practically nothing to upwards of 20 per cent in locally controlled plants. In plants under commission control, the rate of return is limited.

The higher rates of return in locally controlled plants are due to [1] the laying aside of portions of net revenue for future improvements and [2] the diversion of water works funds to meet deficiencies resulting from other municipal expenditures. But in state-controlled plants, commission rulings appear to deny the right of cities to raise, through increased water rates, the revenue necessary to finance future improvements. As an example, the Montana commission (re *City of Helena)* recently held that "the future sale of bonds does not warrant *present* increases to provide for principal and interest payments to commence two or three years hence." Regardless of one's viewpoint on the propriety of diversions to the general fund, it can be agreed that such diversions are to be deprecated unless and until full provision has been made for all of the legitimate needs of the water works, both immediate and future.

Two means of reducing existing confusion suggest themselves: [1] placing all water works under the supervision of state commissions; or [2] promulgating rules of financial conduct which will permit the exercise of local preferences, yet lead to ample financial support for an adequate water works.

State supervision is never likely to be accepted throughout the nation. It has long been a controversial matter, opposed by those who regard it as an unnecessary interference in the right of cities to manage their own affairs. As of August 5, 1948, only five state commissions—Montana, Nevada, West Virginia, Wisconsin and Wyoming—were reported to have jurisdiction over municipally owned water works in the regulation of rates within the corporate limits.

If, in lieu of state supervision, regulations are to be drafted for the "home rule" of water works, they must depart from the general premise of state commissions that, in the approach to the matter of revenue, there is no difference between publicly and privately owned systems.

That there are very definite differences may be seen from the following:

1. Privately owned water works, in order to survive, must receive a rate of return which will assure that new money for extensions and improvements can be obtained at interest rates attractive to investors. There are no such limitations on the financing of publicly owned properties. Money is borrowed, usually on either general-obligation or revenue bonds. The general-obligation bond is a lien on all the property of the city; its salability is not affected by any consideration of the assets or earnings of the water department. Revenue bonds are a lien on the earnings of the water works, but the buyer is interested mainly in the net income and the assurance that the principal and interest on his particular bond issue will be paid out of revenue. He is not primarily concerned with the value of the debt-free property or with whether the city pays any return on such property or not. But the rate in effect must be sufficient, with a safety margin, to pay all the cash obligations of the system.

2. In the privately owned property, bonds are never retired; they are refunded. In the publicly owned system, bonds are generally retired. The private company's earnings on debt-free property are available as stock dividends; with the public system, the debt-free property is owned by the city. Who owns this property, in equity—the taxpayers or the water rate payers—is another moot question; but the decesion on whether or not it should pay interest, and to whom, may be considered a local problem to be determined by local authorities.

3. The difficulty in applying the theory that the municipally operated water utility is "entitled to the same rate of return as that permitted for privately owned utilities" is that *one must establish a value for the property and determine the interest rate.* In some utilities, the undepreciated book value is used, but such an amount is likely to be much less than the value allowed by a court on a privately owned utility. For

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privately owned utilities, these matters are determined by court and commission adjudication; for locally controlled, publicly owned utilities, no such machinery is available. Moreover, the criteria are not the same for both. A return of 5 per cent, for example, may suffice to maintain a solvent private company, but a similar return on a publicly owned property may be less than or much more than needed, depending upon the value of debt-free property and the policies regarding major improvements and other items.

Basis for Public Systems

In publicly owned plants, a practical method is to approach the problem from the standpoint of the *cash* needs, based on adequate estimates of operation and maintenance costs, replacement allowances, and actual interest and bond retirements, together with such amounts as may be found necessary for extensions and improvements. With the total thus determined, one may compute the interest rate required on the book value or appraised value of the property, but this interest rate is not necessarily significant. For the average municipal water works, owning much debt-free property, the interest rate may be relatively low, unless major extensions are being financed at a rapid rate, in which event it may be relatively high. If the high rate is due to fund diversions, that is another matter, which is open to serious question.

Such a budget or cash basis for the determination of gross revenue for publicly owned water works seems to the author to offer a realistic approach to the problem, one which will preserve and defend the water works, yet leave matters of policy to the officials and citizens.

On this basis, the revenue requirements may be considered under two classes: *basic* and *optional:*

Basic
1. Operation and maintenance
2. Debt payments
3. Reserves for:
   a. Replacements
   b. Normal extensions and improvements

Optional
4. Taxes
5. Reserves for major improvements
6. Contributions to other city departments

These items may be described briefly, as follows:

1. *Operation and maintenance.* There should be *adequate* provision for efficient operation and maintenance of the property. This means that the organization should have sufficient, trained personnel not only for bare operation, but to provide competent supervision of office books, records, accounting, and maps and planning. The wage and salary schedule must enable the utility to retain its personnel against the competition of business and industry.

2. *Dept payments.* The revenue should suffice to meet the *actual* interest and retirement obligations on all of the outstanding bonds regardless of the security behind them. Although general-obligation and special-assessment bonds are the legal obligations of the whole or a part of the taxpayers, the payment of interest thereon and the retirement of the principal are commonly accepted as the moral obligation of the water works and as payable out of revenue, similarly to mortgage or revenue bonds.

3. *Reserves.* The word "reserves" is used in an accounting sense. Certain moneys should be taken currently from income, credited to suitable reserve accounts and charged to their corresponding funds; and the cash in these funds should be used only for the purpose for which they are created.

Basic reserves are suggested for replacements and for normal extensions. Replacement allowances should be *just sufficient* to provide for the renewals and replacements which may be anticipated from decade to decade in a property that, on the whole, will continue to be serviceable in future generations. Allowances for normal extensions should not include any major improvements. If a sinking fund for debt amortization is required, there should be a separate reserve and fund. Funds should be kept in cash or negotiable investments and the adequacy of the accumulations should be reviewed at five-year intervals.

The above items cover the *basic* requirements, with which no water works manager, council or commission would disagree. The optional or additional items involve those matters on which there is a difference of opinion and which, in the last analysis, will be decided by the local authorities:

4. *Taxes.* The opinions of committee members on this subject appear to range from no allowance for taxes to one for all of the taxes—local, state and federal—paid by a privately owned utility. There seems to be agreement, however, that taxes should not be included unless adequate payment is made to the utility for fire protection and all free service. Of the 462 cities listed in the A.W.W.A. survey [49], about 43 per cent paid taxes of some sort.

5. *Reserves for major improvements.* If it is local policy to avoid debt, in whole or in part, in meeting the cost of major system improvements, a reserve should be created for this purpose and the funds kept apart, carefully invested and earmarked, without possibility of diversion for other purposes. It is not proper accounting to collect such funds through excessive depreciation rates.

6. *Contributions to other city departments.* The most controversial item among the optional additions to revenue is the contribution of the water works to other departments of government over and above a reasonable charge for services rendered by the latter to the utility. The danger inherent in such a contribution is that, once adopted as a policy, it affords an opening wedge for further claims on the revenues of the water works to supplement the city budget. Such a procedure is, in effect, a charge on the rate payer for the benefit of the taxpayer, and its equity may be questioned. If the debt-free property has been accumulated out of receipts from the water users, how can it be considered the property of the taxpayers, upon which they are entitled to receive a return? Only to the extent that water works debt-free property has been paid for by taxpayers can one justify a "dividend" to taxpayers on such property.

Allocation of Revenue

The second item in the present outline of the Committee on Water Rates has to do with the proportions of gross revenue that should be collected (a) from taxpayers and (b) from customers through commodity rates; and these two groups might be classified also as property and persons, and as nonusers and users.

A water works provides a wider service than merely supplying a commodity. A pure water supply is important to public health; the existence of a water system enhances the value of all property which may be supplied, whether actually served or not; and the availability of water for fire protection safeguards the community and effects large savings in fire insurance.

Although public health and land benefits are real, they are intangible, and there are but few instances in which they appear to have been taken into account in collecting revenue for a water works. Fire protection, on the other hand, is a property benefit that is tangible and may be evaluated and assessed.

One outstanding example of a rate structure which recognizes property benefits in a large way is that of the Washington Suburban Sanitary Dist., where the following taxes, assessments and charges are made: [1] a general tax on *all* property, based on the assessed valuation; [2] a "front-foot benefit charge," where a water main and sewer exist in front of a lot, *whether used or not;* and [3] a "ready-to-serve charge" and a "consumption charge" when water is used [49].

To take a typical illustration, a vacant lot, with water main and sewer in the street, pays 55 per cent as much as the same lot with a house on it using 5,000 gal. of water per month. The front-foot benefit charge, for both water and sewerage, is more than 1½ times the water consumption charge. It is interesting to note that, in this instance, "there is no limitation on the taxing authority of the district."

The theories behind such charges have yet to be developed for specific application. That is one of the tasks assumed, it is understood, by the A.S.C.E.-sponsored joint committee.

For the present, at least, the A.W.W.A. committee is confining its studies on revenue allocation to fire protection (paid by taxpayers) and commodity rates (paid by customers).

Fire Protection Charges

Although the propriety of a charge to the taxpayer for public fire protection has long been acknowledged by the industry, by its managers, boards and engineers, only a minority of municipally owned water works collect any of their revenue in this way.

Based on the A.W.W.A. survey of operating data for 1945 [49], it appears that only 193 out of a total of 462 cities, or 42 per cent, collect *any* revenue on account of fire protection. Of the 462 cities reported, 43 are privately owned and 419 publicly owned. Of those privately owned, 81.4 per cent collect a fire charge, but of the publicly owned, only 37.7 per cent. More striking than these figures, however, is the *range* of the charges made, which varies from a token amount of $0.015 to $4.20 per capita per year. Obviously, the tabulation referred to is far from complete, but it indicates a state of utter confusion.

Previous Methods

Numerous methods have been proposed in the past for determining the proper proportion of water works costs chargeable to fire protection. Three of the methods described in the extensive literature on the subject will be briefly discussed.

The classic paper on public fire protection is that of Metcalf, Kuichling and Hawley [48], published in 1911. The method used in this paper to determine "the approximate percentage of the total cost of water works, involved by the requirements of fire protection service," meaning the percentage of interest, depreciation and taxes, exclusive of "operation and maintenance charges," was as follows:

1. Determine the percentage of the *carrying capacity* of the distribution system chargeable to fire protection on the basis of the ratio between fire demand and total demand, including fire.

2. Determine the percentage of the total cost of the water works invested in the distribution system.

3. Multiply these two percentages together to obtain the percentage of distribution system cost chargeable to fire protection.

4. Add to the product obtained under Paragraph 3 an amount, *based on judgment*, to cover "some slight additional cost in supply and reservoir systems, and substantial increase in cost of pumping capacity."

The difficulty in applying this method is that the element of judgment, covering that part of the plant other than the distribution system, is so large in relation to the "computation" on the distribution system that no precise application is possible. In a separate memorandum to the committee, the author has shown that the percentage added by "judgment" varies from 19 in a town of 10,000 population to 813 in a city of 300,000 population.

Among the other articles in the literature which present differing methods of computing fire protection, two are outstanding—one by John W. Alvord [7], published in 1914, and the second by Robert Nixon [8], published in 1937. Alvord says that:

The proper method of dividing the cost of public and private services is [1] to make a valuation of the plant; [2] to make a study of the value of a theoretical plant, sufficient in capacity for fire service only; and [3] a study of the value of a theoretical plant, capable of domestic service only. The sum of the [2] and [3] study will give a value much greater than the value of the combined plant, and the value of the combined plant should then be divided between fire service and domestic service in proportion to the theoretical values found necessary in each case.

On the Alvord basis, it appears that a very considerable proportion, but less than 50 per cent, of the costs would be allocated to fire protection, and this rule would apply regardless of the size of the city. On the Kuichling basis, however, only the *incremental* costs are used, and the larger the city, the smaller the per capita charge against fire protection. The paper by Robert Nixon, which presents the method used by the Wisconsin Public Service Commission, also allocates the capital costs on an incremental basis.

Of the three methods mentioned above, the Alvord basis would give, by far, the largest result. The author has not noted any situation in which it appears to have been applied to its ultimate requirement. A smaller total fire charge would result from the application of the Kuichling method. Although the Kuichling end results have been frequently referred to, and no doubt considered, by those interested in computing a fire charge, one may infer from the A.W.W.A. survey [6] that there are few if any cities where the fire charge corresponds to a *complete* application of the Kuichling method. From the meager data available, the author concludes that the Wisconsin basis generally results in a charge of 50-70 per cent of what would be obtained with the Kuichling method. The Wisconsin basis appears to have been applied consistently, so that cities of less than 50,000 population receive about 20-30 per cent of their gross revenue from the fire charge. Elsewhere in the nation, with few exceptions, the charge, where made at all, is much lower.

The differences between the methods proposed for computing fire protection costs arise in part from certain basic controversies found in the literature throughout the years. Some of these controversial matters will now be considered.

Relative Importance of Services

On the relative importance of fire protection as compared with general water service in the average community, one finds three viewpoints in the literature: [1] that fire protection is of *prime* importance; [2] that the two are of *equal* importance; and [3] that fire protection is of *less* importance than the combined needs for all other services.

On the first assumption, the cost of a system to provide fire protection alone would be compared with the cost of a system to provide both, and the *increment only* would be charged to normal uses. This assumption dates back to a time when many plants were installed mainly to furnish fire protection.

If the services are of *equal* importance, all costs of the combined system should be allocated to the two uses on the basis of the estimated costs of two hpothetical systems, one for fire and the other for general service. This is the assumption adopted by John W. Alvord.

The third viewpoint recognizes that conditions have changed since the earlier years and the municipal supply has become so vital to the health and business of the community that the general service has become the more important aspect of a water supply. Hence, fire protection should be charged only with the increment in cost required to enlarge the plant to meet fire demand.

Both the Kuichling and Wisconsin bases are premised on the general assumption that, as far as capital costs are concerned, only incremental costs are chargeable to fire protection. The differences in results arise out of differences in other assumptions.

Ratios of Demand

The second controversial matter has to do with the ratio between the amount of the fire demand and the amount of demand for all other purposes, which establishes the increment of capacity chargeable to fire. Three standards for fire demand, based on population, have been used [9]: [1] those of John R. Freeman, who suggested, in 1892, both the maximum and minimum number of fire streams; [2] those proposed in 1897 by Allen Hazen and Emil Kuichling; and [3] those submitted by the National Board of Fire Underwriters in 1910. The values resulting from the several formulas which have been presented to the committee vary considerably. One example may be given here as a comparison between the Kuichling and Wisconsin bases. For a town of 50,000 population, the Kuichling basis determines the *carrying capacity* of the distribution system chargeable to fire by using a fire demand of 4,950 gpm.; for a town of the same size, the Wisconsin commission, using the *minimum* Freeman curve and assuming 200 gpm. per fire stream, adopts a fire demand of 2,700 gpm. for determining the percentage of the *cost* of the distribution system chargeable to fire.

Recently, on May 4, 1948, the National Board of Fire Underwriters issued a bulletin [10] containing "material modifications" of the old rules, which were based on total population only. In this bulletin, the requirements for residential areas and industrial plants are separately discussed.

The determination of the second factor in this ratio, the amount of *demand for all uses other than fire* (which may occur during a fire), also offers opportunity for a difference of opinion. In the Kuichling standard [9], this maximum rate was assumed "to be *twice* the average daily rate therefor, in the plant furnishing only domestic service, and 1½ times the average daily rate therefor in the plant furnishing both domestic and fire protection service."

The underwriters state that "a system must be capable of supplying a reasonable quantity for fire protection for a period of ten hours, in addition to domestic consumption at the maximum daily rate, for any day within the past three years." The Public Service Commission of Wisconsin, however, has based its computations on the maximum *hourly* rate. Obviously, differences in assumptions on this one item result in marked differences in results.

Operation and Maintenance Costs

The foregoing relates to capital costs. A review of the literature also shows a wide divergence of opinion on the amount of operating labor and maintenance chargeable to fire protection.

If fire protection is of *equal* importance with normal service, the ratio of the operating costs of each of the two hypothetical systems will determine the percentages of the operating costs of the combined plant chargeable to each service. This is the logic of John W. Alvord. He assumed that the plant built for fire protection would not be in operation 99 per cent of the time, but that the engines would be warmed up, the pumps turned over once in a while and everything, including the operating force, would be ready for a fire. On such a basis, more than 50 per cent of the operating expense of the combined plant would be chargeable to fire.

But, on the other hand, if one follows the logic of the *incremental* theory, the domestic plant would carry its full quota of operating labor, and only the *additional* labor and expense required in a larger plant would be chargeable to fire. Generally, this charge would be relatively a small amount. Kuichling [9] said, in reference to operating and maintenance costs, that the "data are meager [but] it is believed that these charges lie between 5 and 10 per cent of the total annual operation and maintenance charges, including taxes, but excluding depreciation, interest and profit allowances." In *Water Works Practice* [11], data are presented on the "annual operating and maintenance costs attributable to fire protection service, Indianapolis Water Company," as submitted in 1924 to the Public Service Commission of Indiana. In this tabulation, approximately 25 per cent of the pumping expenses and nearly 40 per cent of the distribution expenses, plus other items, were allocated to fire protection.

The Wisconsin Public Service Commission allocates operatiag and maintenance expenses under a set of rules which first divide expense into "capacity" and "output" costs and then assign "capacity" costs to general service and fire protection on the basis of the ratio of fire demand to total demand, while "output" costs are determined on the basis of water actually used for fire. These rules are fairly complicated and no two engineers, working independently, would be likely to arrive at the same total. In the example given by Nixon [8], more than 20 per cent of the total annual expense is charged to fire protection, which would appear to be in excess of the amount that would result from the strict application of the incremental theory, based on a comparison of two hypothetical plants.

Basic Assumptions

From the foregoing discussion and illustrations, and from many other examples in the literature, it is apparent that the subject of fire protection is in great confusion as to both the theories involved and the methods of application. This confusion goes back through the years and the thinking of many writers and the decisions of courts and commissions.

In spite of this background, however, the committee has the temerity to set as its objective the outlining of a basis for the

computation of fire protection charges that will be relatively simple in its application and yet reasonable in amount in the light of present conditions.

The following basic assumptions are presented for consideration:

1. The prime function of a water works today is to provide general service to water users, and only the *increment* in costs, both capital and operating, is chargeable to fire protection.

2. The demand of water for fire—both the amount and the duration in hours—may be based, for the present, on the standard requirements of the National Board of Fire Underwriters.

3. The percentage of *plant capacity* required for fire may be taken as the ratio of the "fire demand" to "fire plus general service demand" for the *duration in hours*, as specified by the underwriters; and the percentage of *plant cost* chargeable to fire protection would be the percentage of capacity multiplied by the ratio of increased cost to increased capacity.

4. The dollars chargeable to fire protection on account of capital costs, would be obtained by multiplying the percentage of *plant cost* obtained under Paragraph 3 by the interest, taxes, depreciation and return on investment for the *applicable* portions of the plant; plus all charges involving hydrants and their connections.

The applicable portions of the plant would include all production and distribution facilities but would exclude hydrants and connections, consumer's services and meters, and most of the investment in office and shop.

5. The dollars chargeable to fire out of operating and maintenance expense would be based on an estimate of the *additional expense only* required by a larger system, on the assumption that the system needed to supply general service only would require a complete labor force, office, shop and administrative overhead; plus the cost, at the existing commodity rates, of the water actually used for fire.

6. If storage is available *in excess of* the needs for general service, all costs connected with such storage should be charged directly to fire; but such excess storage will reduce the fire demand on the balance of the system and hence reduce the ratio of fire demand to total demand and the percentage of the balance of the system chargeable to fire. Excess raw-water storage will reduce the ratio applicable to the supply facilities; excess clear-well storage will reduce the ratio applicable to production facilities, except high-lift pumping; and excess elevated storage will reduce the ratio applicable to high-lift pumping, transmission and distribution, except in that portion of the distribution system between the elevated tanks and hydrants.

These bases for the determination of the fire protection charge are submitted to the committee and the Association for their constructive comment.

Rate Structure

The next subject to be discussed is the distribution among water users of the balance of the revenue required by the water system—that is, the commodity rate structure. The items to be considered are, first, the service charge, whether based on customer costs or on "demand" or "ready-to-serve" costs, or both; and, if the demand costs are to be included, the basis for fixing their amount and the basis for their distribution among customers. Second, rules are desirable for the determination of the number of steps, the unit rates for each step and quantity limitations within which each unit rate shall apply.

Service Charge

Although a "service charge" has long been recommended as a proper feature of a rate schedule, it has not been generally adopted, as such, in rate structures. Apparently it has not been understood by the public and has, therefore, been rejected, although minimum charges have been accepted and minimum bills, in combination with adjusted unit commodity rates, are used to produce the equivalent of a service charge. These matters are details that can be worked out. The real problem is to determine the equitable allocation of costs between users of different classes; and this determination involves the service charge.

The Committee on Water Rates of the Michigan Section, A.W.W.A., gave careful consideration to the "demand" charge and discarded it as a basis for the service charge to the great majority of water users. It is a theory applicable to fixing fire protection charges, and it may be applied equitably to large users served through recording meters which supply the necessary evidence of "demand." The development of a maximum-demand water meter would extend the field of application of the demand theory to correspond with its applicability in the electrical industry, from which the theory was derived.

At this point, it may be advisable to mention a difference between "ready-to-serve" and "demand" costs that could well be accepted, although to date these terms have been used interchangeably. A "ready-to-serve" charge could be applied when a water main is in the street in front of a vacant lot, and there is much justification for a charge under such circumstances. A "demand" charge, on the other hand, should not apply except to *users of water*, either intermittent or regular. Such a charge would presumably be based on the ratio of the maximum rate of demand to the average rate of use.

In rejecting the demand theory, particularly as applicable to the domestic user of water, the Michigan committee returned to the basis originally adopted by both the New England Water Works Assn., and the A.W.W.A.

In 1914 and 1916 an N.E.W.W.A. committee on water rates recommended a service charge covering: [1] all costs connected with service pipes and meters; [2] the cost of reading meters, keeping records, billing and collecting; and [3] the cost of all "lost" water, "reckoned at the lowest rate charged for any water that is sold" [10]. This report was the subject of much discussion, the opposition contending that the service charge should also include "those elements of cost which are proportionate to the maximum demand." This argument was premised on a "method set out by Hopkinson of England, and Henry L. Doherty in this country, treating of rates for electrical supply."

According to the latter theory, the service charge should include all *customer* costs, "such as billing, meter reading, accounting, collecting, meter testing, etc.," plus all *demand* costs—including mainly profit, taxes, insurance and depreciation—not chargeable to fire protection. The balance of the expense, chiefly pumping costs, determined the commodity rate. In an example given, about 85 per cent of the total expense, exclusive of the fire charge, was allocated to the service charge, and the balance, or 15 per cent, determined the commodity rate.

In 1917 another writer [10] took vigorous exception to the recommendations of the N.E.W.W.A. report, insisting that the service charge "should be constituted of a consumer charge and a capacity charge"; the capacity charge should "be the amount necessary to keep the plant ready for service and intact were not a drop of water delivered for the entire year" (including interest and depreciation on the entire plant); but "maintenance and profits should be incorporated in the output charge." This writer's position was that "the function of a service charge is more to stabilize than to produce a revenue" and, if "due to the ups and downs of prosperity," too much dependence is put on the output charge, "the revenue will at times become inadequate." But he also aimed at a commodity rate that would enable a water works to justify sales to "a large consumer . . . at any rate which . . . will add to the net revenue of the plant, even though the rate is below the average cost as built up by administration, operating, depreciation, interest and profit." One may conclude that no such basis of justification for an excessive service charge should be considered by the committee.

The answer of Allen Hazen [10] to the argument for this basis was that, if it "is carried out to its logical conclusion, it puts too large a burden on the smallest takers"; and "that the method of calculation" of the N.E.W.W.A. committee "puts all the load on the smallest consumers . . . that is their fair share."

In 1923 the A.W.W.A. accepted the report of its committee on a standard form of rate schedule, which was in accord with the previous recommendations of the N.E.W.W.A. committee. *Water Works Practice* [10], however, neglected the recommendations of the 1923 committee and reverted to a basis for the service charge substantially as proposed by previous advocates of a relatively high charge, except for the following qualification: "It sometimes happens that an analysis of cost in a particular system carried out in this way will result in putting a considerable proportion of the total cost on the service charges. *Theory should not be carried to extremes*, and regardless of calculation, it is best to limit the service charges in all cases to reasonable amounts, not greatly exceeding those actually adopted in other cases. *The consumption charges should, in all cases, carry the major part of the entire cost of service.*"

Down through the years, the advice of the manual appears to have influenced the thinking of many writers, each making his own interpretation, with an end result of confusion and a wide diversity in schedules. In fact, only a few schedules appear to have followed the "demand" theory to extremes, and, although the writers claim to have used the theory, the service charges proposed by them are not materially higher than a proper customer charge would be.

The reasons for rejecting the "demand" charge as an element of the service charge were set forth at some length in the Michigan Section committee report [10] published in 1949. The details need not be repeated, but, briefly, there are three reasons:

1. There appears to be no logical place along the line at which one may stop in determining the amount of demand charge to be included. The theory cannot be applied except arbitrarily or on the basis of judgment and precedent elsewhere.

2. There is no basis for the equitable distribution of the demand charge among water users, except through the development of maximum-demand meters or for large users served through recording meters. The past practice of distributing a demand charge on the basis of meter capacity ratios is not equitable in that it

ignores all differences in conditions among 90 per cent, more or less, of all customers and assesses a considerable part of the whole cost uniformly upon these customers.

3. The addition of a demand charge to a proper customer charge will invariably place an undue burden on the smaller user and result in too low a commodity rate to the larger user. An application of the effect of such a combination on the rate structure of Detroit has been made by Hal F. Smith [13].

The present author, therefore, recommends that a service charge include:

1. All commercial expense and a suitable portion of the administrative expense and overhead costs, the total of which is to be divided *equally* among all accounts.

2. All expense arising out of meters and services, with a share of administrative expense and overhead, the total of which is to be distributed among accounts on the basis of *meter costs.*

There should also be a minimum charge, based on the commodity rates. For the smallest meter, this minimum should be the service charge, plus the cost of, say, 100 gpd. per meter. And it has been suggested that a minimum charge for all other sizes of meters be made on the basis of the service charge for each meter, plus the cost of a minimum quantity of water allowed for each meter, based on the squares of the diameters of the several meters.

Commodity Rates

Considering the commodity rates, there are three questions to be answered: [1] how many steps are desirable? [2] how are the unit rates determined for each step? and [3] what are the rules for fixing step quantity limitations? The following answers to these questions are presented in the Michigan Section report [10]:

1. In line with the recommendations of *Water Works Practice,* three steps are suggested, referred to as domestic, intermediate and wholesale.

2. Unit rates are determined thus:

a. The *wholesale* unit rate is obtained by dividing the total of all production and transmission costs (capital, operating and maintenance)—excluding deductions chargeable to fire protection and including a portion of administrative expense and overhead—by the total annual pumpage.

b. The *intermediate* unit rate is obtained by adding the intermediate increment to the wholesale rate. The intermediate increment is obtained by dividing the total costs—exclusive of deductions chargeable to fire protection—arising out of distribution mains larger than 6 in. by the water sold through all meters except sales at the wholesale rate.

c. The *domestic* unit rate is obtained by adding the domestic increment to the intermediate rate. The domestic increment is obtained by dividing the total costs—exclusive of deductions chargeable to fire protection—arising out of distribution mains 6 in. and smaller plus the cost of all lost water, by the water sold through all meters ¾ in. and smaller.

3. Step quantity limitations must be adopted which, when applied to the unit rates, will produce the necessary revenue. As an initial determination, it is suggested that the domestic rate apply up to a quantity equal to twice the average rate of use through all domestic meters, ¾ in. and ⅝ in.; that the intermediate rate apply up to a quantity equal to twice the average rate of use through all intermediate meters—say, 1, 1½ and 2 in.; and that all quantities over the intermediate limit fall under the wholesale rate.

The foregoing rate structure is offered as a basis for the average city and the average customer using year-round service in a normal manner. It does not provide the answer for those special situations involving intermittent and abnormal uses of water. On some of these problems, the committee hopes to make specific comments later.

General and widespread comment on all of the above, from all interested parties, is earnestly solicited by the committee.

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Renovating Water Meters

Water Companies, on the whole, and also several of the more progressive municipally owned Water Departments, have found that a little dressing up of overhauled meters before returning them to the customers' service has a desirable psychological effect on the customer. The spray gun and gilt or silver lacquer or a combination of the two is the most universally employed method of dressing up old meters after they have been overhauled and tagged "O.K." on the test bench.

Mr. La Verne Trentlage, Superintendent of Meters in the Water Department of Elgin, Ill., has evolved a scheme which goes the spray-gilting method one better in making "new" meters out of old ones. In the Elgin scheme the metal parts of the meter are given a treatment which removes the oxidized or carbonated coating from the metal and leaves the parts as metal-bright as when turned out by the manufacturer.

Cleaning and Brightening Procedure

(1) Dip meter parts for 10 minutes in *hot* Trisodium Phosphate solution (2½ lbs. or more of T.S.P. in 10 gallons of water).

(2) Remove meter parts from T.S.P. solution and rinse in *hot* water to remove the alkali.

(3) Dip the parts in Muriatic Acid solution (1 part 18 degree Muriatic Acid—to 2 parts of water). Allow to remain in this acid bath for approximately 15 minutes, or longer if necessary. Remove and rinse in hot water.

(4) To brighten to original lustre, immerse in the "bright-dip" solution (1 part 38 degree Nitric Acid, 1 part 66 degree Sulphuric Acid and 1 part water, plus a handful of common salt). Leave the parts in the bright dip for 5 to 10 seconds, the length of time depending on the composition of the metal and degree of brightness desired.

(5) Remove and rinse in *boiling* water to remove acid.

(6) To keep the parts from dulling on standing, a "stabilizing-dip" (especially prepared for this purpose) has been developed by General Chemical Company). After the rinse, the parts are dipped into this solution, removed and allowed to drain and dry.

Notes of Caution: Always add acids to water and *not* water to acids when making dilutions. This will preclude over-heating and spattering of the acid. Be careful to avoid splashing of the acid when dipping the meter parts. In case acid accidentally splashes on hands or face, wash at once in clean water to avoid an acid burn. Spattered acid is also hard on clothing and shoes. Rubber aprons and gloves are good protection.

Do not use iron or steel wire for dipping meter parts. Copper or monel metal wire is satisfactory.

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WATER RATE INCREASES and PUBLIC RELATIONS*

JOHN H. MURDOCH JR.

Vice-Pres. and Counsel, Water Works Service Co. Inc. New York

IN this paper the author has made an assumption, then established three premises, reached a conclusion and, finally, suggested a plan of action.

It has been assumed that the only water utilities which contemplate rate increases are those whose officers feel that the existing rates are too low to cover adequately the operating expenses and fixed charges while leaving enough net income to assure the financial integrity of the enterprise and enable it to attract such additional funds as it may need for capital betterments and replacements. In brief, it has been assumed that the managers feel the existing rates are insufficient to cover present costs.

Three premises are then established:

1. When the water service being rendered is satisfactory, the public does not object to increases in rates sufficient in amount to cover the entire cost of service.

2. If the water service is unsatisfactory, the public will object to increases in rates even though the proposed increase is only enough to cover increases in costs.

3. Rate increases proposed in connection with acceptable plans to correct faults and deficiencies of plant and service will not be subject to objection.

On the basis of these three premises, the conclusion is reached that the public has more interest in service than in rates. Two plans of action are therefore suggested: First, if the service is now satisfactory but the existing rates are too low under present price conditions to cover all costs and attract new capital to take care of growing demands, then the rates should be increased. Second, if the service is now unsatisfactory and the rates are too low under present price conditions to cover all costs and attract the capital needed to correct existing faults and care for growing needs, it is necessary to prepare plans for improved service and secure increases in rates in sufficient amount to cover all new costs of service.

To avoid misunderstanding, the phrase "cost of service" should be defined. When used in this paper that phrase, or any variation of it, means all operating expenses of the enterprise; all taxes payable; either amortization of debt principal or depreciation; interest on debt; and enough net income to maintain the credit and financial integrity of the enterprise and to enable it to attract needed new capital from time to time.

It should be emphasized that when the author refers to "objection" or uses the phrase, "the public will not object," or similar language, objection by customers is meant, not official objections by utility commissions or other governmental bodies, except when a popular demand by customers is reflected.

Validity of Premises

How valid are the premises from which the conclusion is drawn? Frankly, they represent the author's opinions based on experience and on observation of the workings of human nature. From a few instances no absolute demonstration can be made that all people will react in the same way under like conditions. At that point opinion takes over. However, it may be worth while to consider several typical situations.

City *A* is served by a water system established more than 60 years ago. In the early days the utility had great difficulty because of industrial contamination of its source of supply, with public opinion supporting industry and with the courts forbidding the collection of water charges until a new supply could be developed. When such a supply was ultimately secured, the courts, after an unpopular fight by the water utility, established the legal principle that contamination of a public water supply constitutes a public nuisance which may be restrained. A program of continued plant development and improvement, well abreast of community growth, carried out by a succession of energetic, efficient and personally popular managers, has changed the old antagonism against everyone connected with the utility into the present attitude of friendliness. Recently it was decided that there was no possibility of prospective increased water usage bringing in enough new revenue at existing rates to overcome the rapid rise in operating expenses and taxes. The utility was not earning its cost of service, with the result that it was having difficulty in getting needed new capital. As there was no possibility of reducing expenses or even of holding them at the current level, an increase in rates was necessary.

The entire situation was laid before local leaders, newspaper editors, members of the city council and other public officials. All were given opportunities for full and open discussion and access to relevant data. The difficulties of the utility and the proposed increase in rates were discussed with the managers of the local industries and their accounts. These men understood their rights and realized their civic and social responsibilities. An increase equivalent to 20 per cent in all rates was approved without protest and the community has continued happy and content.

The service was satisfactory, more revenue was needed and the public did not object to a very substantial increase in rates. Similar instances could be cited to support the author's first premise that: *when the water service being rendered is satisfactory, the public does not object to increases in rates sufficient in amount to cover the entire cost of service.*

At City *B* very different conditions existed. There were two dissimilar sources of supply—a river with hard water and an upland, impounded, soft water supply. The first was filtered and softened but the quality of the water in the river varied radically, often and suddenly. On occasion tastes and odors developed and unsatisfactory water got by the plant and into the distribution system. For one reason or another, almost 10 per cent of the time water with a hardness content will above the standard was delivered to the customers. There were complaints of turbidity in the distribution system, although plant records indicated that no water with excessive turbidity had been delivered into the system. Water from the river source reached parts of the city at all times and other parts of the city at certain seasons and certain hours. Still other areas had the soft mountain water continuously. Some customers were well satisfied with the quality of the water while others were completely discontented.

The city covered a territory of high hills and deep valleys with very steep slopes between. The water distribution system included a series of districts with elevated storage and booster pumps. The city grew rapidly during the war and has held and increased its population. In several different sections, consumers' water demands had outgrown the carrying capacity of the mains. Especially at the upper edges of the low-service district, along the steep hillsides, there was a lack of pressure. The dividing line could not be moved downhill by a mere change in the location of the valves because the mains into the high-service District did not have the required extra capacity to carry the loads which would have been added.

The situation would not have been difficult if the water utility could have financed various indicated improvements, but the fact was that operating expenses and taxes were absorbing almost all of the revenues. Less money was coming to net income than twenty years before, while since that time investors had put about $1,000,000 of new funds into the system. Much more new money was needed for extensions into newly opened residential districts—not real estate developments of promoters—as well as for the strengthening and improving of the pumping station, the treatment plant and the distribution system in the older sections.

When an increase in rates was proposed, determined opposition developed. It was not claimed that the suggested rates would impose a hardship on customers but that they were too high for the kind of service being offered. The answer that the community was not even paying the cost of the service it was getting, which was the fact, did not lessen the objections. The outcome was the approval of the proposed rates coupled with the condition that an ambitious program of system rehabilitation and improvement be inaugurated at once.

This situation is an example of unsatisfactory service and public opposition to a rate increase designed merely to restore former net-income ratios. The opposition was caused by and centered upon the poor service, not on the dollars and cents involved in the new rates. This and similar experiences form the factual basis for the author's second premise: *if service is unsatisfactory, the public objects to increases in rates even though the increase is only enough to cover increases in cost.*

City *C* presents another typical situation, although in extreme form. The water system serving this city was established about 70 years ago in an old but steadily growing community. Because the city is located at the crest of all the watershed divides in the district, there are no large streams within reach and no substantial ground water supplies are available. Water works engineers and financiers who had been successful elsewhere tried for more than ten years to develop a dependable supply and, after repeated failures, gave up in disgust. The people of the town had grown to expect periodic curtailment of supply and high turbidity. A group of local businessmen took over, invested their money in large impounding reservoirs on small streams and in one of the every early rapid sand filter plants in the country—a plant still rendering splendid service. Every service was metered and water rates were increased.

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Within two years after the change in control the city had adequate and satisfactory water service and the company had become a financial success. The people of the city were perfectly content with the new higher rates for water; they were receiving service which they had despaired of ever getting.

All went well for twenty years and then real trouble arrived. The management, lulled into a sense of security by what later proved to be a glaring engineering overestimate of storage reservoir capacity, failed to give weight to evidences that the growth of the city was exhausting the available storage. When drought struck, there was no reserve storage, and on Christmas Eve the state department of health took control and severely rationed domestic use, shut off industries and held the distribution reservoir in readiness for fire. It was months before normal usage could be allowed.

A new manager with good engineering training and experience was secureed. He developed plans for increased storage in impounding reservoirs to assure adequate supplies for several years of continued growth of demand. Armed with these plans, he and the other officers carried through a program for increased rates designed to meet the entire cost of service. Although this campaign had to be undertaken against a background of well deserved antagonism to the management, it was found that a frank presentation of all the facts to the leaders of the community resulted in a spirit of good will and cooperation. The head of the largest industry and the one hardest hit by the proposed rates studied the figures and then stated that he would rather pay more money for an assured supply than have cheap water with the risk of plant shutdowns. The rates were increased, the improvements were made and the enterprise has been able to give good service during a drought and grow with the community. The people want water service and are willing to pay what it costs, which bears out the premise that: *rate increases proposed in connection with acceptable plans to correct faults and deficiencies of plant and service will not be subject to objection.*

Public Relations

It appears logical to conclude from these three premises that *the public has more interest in service than in rates.*

The author is firmly convinced that water works men have made several mistakes in their relations with the public: [1] not knowing the costs of service; [2] not educating the public concerning these costs; [3] thinking about and advertising cheap water rather than valuable service; [4] trying to persuade the customers that they should not expect better service because they pay so little that the utility cannot afford better service; [5] treating the customers as though they were patrons of a bargain basement clearance sale when they really want a superior product and are ready and willing to pay the cost.

Many water plants today have such low rates and high capital costs per average customer that each new customer is a drag on the system rather than a source of strength. This condition is against the public interest, and management should study the economics of its undertakings, consider and work out the true costs of service and then educate the community in these matters.

If a system is giving all the water service the people want and its revenues are now entirely adequate to cover the costs, so that the money required for improvements and extensions is always available, then a rate increase is not needed. It is necessary merely to be alert and keep abreast of the changing times. Experience teaches, however, that many managers are in ignorance of the extent of public dissatisfaction with the water service. A genuine study should be made to learn the true facts.

The management of a system which has been giving satisfactory service but which is not now receiving sufficient revenue to cover present costs should boldly go after increased rates. Higher rates should be sought, not because the utility is entitled to them—as it is—but because the customers need the service which can only be continued if completely adequate revenues are available. The public will not object if the facts are sound and a good job of salesmanship is done.

A plant where the service is unsatisfactory, deficient in one way or another or perhaps in many ways has a much harder task to perform. The author suggests a study of the entire situation by experts—engineers, chemists, bacteriologists, geologists, public opinion analysts, bankers and lawyers. It is necessary to know what the people think they want in the way of service. Then the management will have to find how much this service would cost in capital funds and operating expenses. The bankers and public opinion analysts will be able to say what annual revenues would be required to make it possible to raise the capital funds and whether the customers are really anxious enough for the service to pay that kind of money. Perhaps plans will have to be modified to bring desire in line with willingness to pay. The public and its leaders must be consulted, and, in the end, the plan must be one in which the community has pride and which it will support.

The public objects to paying for unsatisfactory service. It wants good service—better, often, than is now rendered. Once it understands the facts, the public is willing to pay the cost.

WHAT LEAKS COST

SIZE OF OPENING	AIR		STEAM		WATER	
	Number of Cu. Ft. Wasted per Month 100 Lbs. Pressure	Total Cost of Waste per Month @ 10c per M Cu. Ft.	Number of Lbs. Wasted per Month 100 Lbs. Pressure	Total Cost of Waste per Month @ 30c per M Lbs.	Number of Gallons Wasted per Month 40 Lbs. Pressure	Total Cost of Waste per Month @ 10¢ per M Gals.
1" / 2	17,798,400	$1,779.84	605,000	$483.00	1,331,000	$193.00
3" / 8	9,979,200	997.92	460,000	276.00	692,400	108.00
1" / 4	4,449,600	444.96	203,000	121.80	307,700	48.00
1" / 8	1,114,560	111.46	50,500	30.30	76,900	12.00
1" / 16	278,640	27.86	12,750	7.65	19,200	3.00
1" / 32	69,552	6.96	3,175	1.91	4,800	0.80

WATER SERVICE AND SEWER RENTS

The following interesting decision is reported by the Municipal Legal Information Service of the New York State Conference of Mayors and Other Municipal Officials:

"On October 11, 1940, the Court of Appeals, Richmond county, Ohio, held that the city of Mansfield had authority by ordinance and rules and regulations issued thereunder to shut off water at premises which are delinquent in their sewer rental payments. Pointing out that it is well settled that a city may shut off water for non payment of a delinquent water bill, the Court considers the direct question involved in this case of the power of a city to discontinue one service for failure to pay for another service, and holds that the sewer and water systems are so closely related as to be considered one transaction as the operation of the sewage system is dependent upon the water supply, therefore, it is reasonable to shut off water for nonpayment of a delinquent sewer rental bill. The court cites and relies upon the case of *Dodd v. City of Atlanta*, 113 S. E. 166, which reached the same decision as was reached in the instant case. *Gatton* v. *City of Mansfield.*"

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3. Regulate fire flows between zones of unequal pressures.
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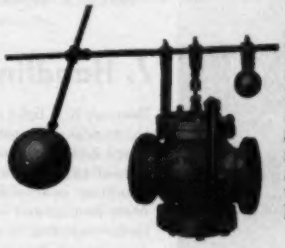

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Because it is light in weight and easy to handle, Transite Pressure Pipe keeps handling costs down. Loading, unloading, and all other subsequent handling operations are simplified. More footage can be hauled per truckload—reducing trucking costs—and distribution along the trench is easier and more quickly accomplished. Moreover, mechanical handling equipment is not necessary except where larger sizes are being used; the pipe sections are easily lowered into the trench with rope slings.

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*Transite is a Johns-Manville registered trade mark

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Two factors give Transite Pressure Pipe exceptional resistance to corrosion: (1) the corrosion-resistant materials of which it is made; (2) the especially developed Johns-Manville process of manufacture which imparts a high degree of chemical stability to the finished pipe. This high resistance to corrosion has been substantiated by numerous installations. Many of these are serving as replacements in soils so destructive that the useful life of the pipe materials previously used had been seriously curtailed.

4. Internal corrosion:

Transite Pipe, because of its asbestos-cement composition, is not affected by tuberculation. Therefore, it is not necessary to resort to pipe of larger diameter to offset the internal effects of this costly form of pipe corrosion. And because progressive reduction of delivery due to tuberculation capacity is never a problem in a Transite pipe line, pressures and flows remain high—pumps operate at higher efficiencies. These factors are often reflected in better service and lower water rates in communities served by Transite lines.

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Transite's success in combatting underground water losses is due to a combination of two factors: (1) the design of the Simplex Coupling used for assembly; and (2) the ability of the pipe to maintain its strength in service. The easily-assembled Coupling consists of a Transite sleeve and two rubber rings which form a tight, flexible joint. The ability of Transite to maintain its strength in service is due to its exceptional resistance to corrosion, as proved in thousands of installations under a wide variety of soil conditions.

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Transite's flexible joints effectively absorb the vibration of heavy traffic—an especially important factor where pipe is laid under busy highways, or near railroad and street car tracks. Because each joint is capable of deflection up to five degrees, the entire line has a flexibility not ordinarily found in other types of waterline construction. This helps compensate for soil movements and other stresses to which the pipe may be subjected . . . provides an effective safeguard against costly pipe failures.

7. Maintenance:

In thousands of communities, Transite Pipe—with its advantages of joints that remain tight and flexible, its corrosion resistance, and immunity to tuberculation—provides low-cost water transportation that requires little, if any, maintenance. Transite lines do not have to be cleaned, lined, or replaced because tuberculation has reduced their original capacity. Reports from communities all over the country prove that Transite's asbestos-cement structure provides economies that continue through the years.

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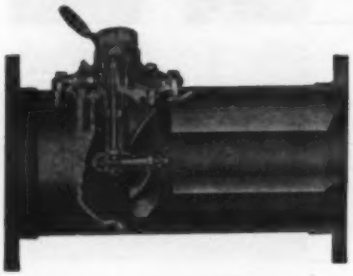

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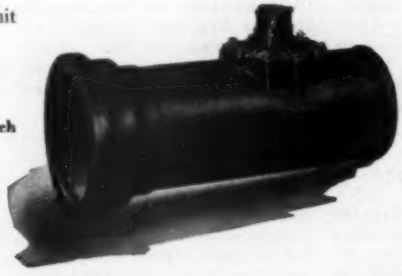

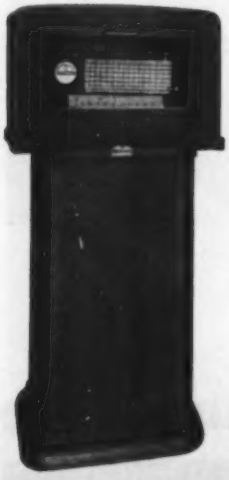

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LOSS OF HEAD IN PIPES AND FITTINGS

THERE are numerous times when a water works engineer wishes to know the loss in head in some particular line. Information on this subject is not lacking but often is scattered in various texts and magazines. Diagrammatic charts, prepared by the application of the Hazen-Williams, and Scobey formulas for flow of water in pipes have been developed as aids to the solution of problems involving loss of head. Tables and charts of loss of head through valves and fittings are likewise available from various sources and authors.

In an attempt to bring these data tables, charts, and diagrams together in one place the following collection is presented. Together with such running comment as is necessary, the information in the following pages should be sufficient to solve any problem in loss of head.

Flow of Water in Pipe[1]

The carrying capacity of a pipe line may be regarded as the index of its hydraulic efficiency. Selection of the most suitable hydraulic characteristics to satisfy the economics of a given installation usually involves consideration of several alternate procedures, and comparisons of their respective characteristics, before the most appropriate choice can be made. These comparisons can only be as valid as the underlying hydraulic assumptions they depend on, hence the importance of suitable expressions correctly formulating the proper relationships involved.

Many studies have been made to determine these relationships, and many formulae developed to express them. In 1775, Chezy, a French engineer, offered his well-known formula for the flow of water in open channels and closed conduits:

$$V = C\sqrt{rs},$$

"C" being a coefficient at first supposed to have a constant value, but now known to vary with the velocity, slope, hydraulic radius, and with some factor representing influences of contact surfaces. The Kutter elaboration of the Chezy formula reads:

$$V = \left\{ \frac{\frac{1.811}{n} + \frac{0.00281}{s} + 41.66}{1 + \frac{n}{\sqrt{r}}\left[41.66 + \frac{0.00281}{s}\right]} \right\} \sqrt{rs},$$

in which "C" of the Chezy formula has been developed into the bracketed expression shown at left, which also introduces a new variable "n", supposed to represent all retarding influences. Unfortunately, however, the value of "n" varies somewhat for pipe, both with size and velocity. Now if we examine for a moment the basic formula

$$hf = \frac{f L V^2}{2gd}$$

which can be established by the usual hydraulic reasoning, we find the Chezy formula recognizable in it, and also the well-known formulas of Darcy Weisbach and Fanning. All these suffer in a basic respect, in that the friction "constant" does not remain constant throughout the range of application. In the early 1900's these discrepancies began to create a definite reaction against the use of the basic simple assumption that $V = C\sqrt{rs}$*, culminating in the presentation of the Williams-Hazen formula. In other words, more critical scrutiny and application of available data indicated that the loss of head does not vary as the square of the velocity, but in accordance with a value lying somewhere between 1.70 and 2.00. It is now fairly well understood that theirs (i.e., the exponential type of formula) is preferable to any other form; also that losses within most closed conduits at velocities within the range of ordinary extremes of service require what Scobey calls "a compromise value somewhat less than 2.00".

*Convertible into the general formula $H = \frac{V^n s}{D^y}$;

The Williams-Hazen formula is now widely accepted, and reads:

$$V = C\, r^{0.63}\, S^{0.54}\, .001^{-0.04}, \text{ where}$$

V = mean velocity of flow, in feet per second.
C = "coefficient of retardation," so-called.
when H = 1000s, x = 2, and y = 1.
r = mean hydraulic radius of the pipe, or diameter D ÷ 4, in feet.
s = hydraulic grade or slope, in feet per foot of length of a pipe of uniform size.

or

$$S^{0.54} = \frac{V}{C\left[\frac{D}{4}\right]^{0.63} \times 0.001^{-0.04}}$$

$$= \frac{4^{0.63}\, V}{1.318\, C\, D^{0.63}}$$

$$S = \frac{4^{1.587}\, V^{1.852}}{1.318^{1.852}\, C^{1.852}\, D^{1.167}}$$

$$= \frac{3.0236\, V^{1.852}}{C^{1.852}\, D^{1.167}}$$

$$S_{1000}\left[\begin{matrix}\text{Loss of Head}\\ \text{in Feet, per}\\ \text{1,000 Feet}\end{matrix}\right] = \frac{3023.6\, V^{1.852}}{C^{1.852}\, D^{1.167}}$$

$$= K\frac{V^{1.852}}{D^{1.167}}$$

when $\begin{cases} C = & 90 & 95 & 100 & 105 & 110 & 115 \\ K = & .727 & .657 & .598 & .546 & .501 & .461 \end{cases}$

or $\begin{cases} C = & 120 & 125 & 130 & 135 & 140 \\ K = & .426 & .395 & .367 & .343 & .321 \end{cases}$

Loss of Head Charts Based on the Hazen-Williams and Scobey Formulas

In the following pages appear four charts (Fig. 1, 2, 3, 4) for determining loss of head in lineal pipe lines. The first three were developed from the Hazen-Williams Formula and apply to any pipe. The last was developed from the Scobey formula and is applicable to concrete pipes.

Figure 1 was prepared by William P. Creager,[2] Chief Engineer, The Power Corporation of New York, and was originally published by John Wiley and Sons in the Hydro-Electric Handbook, by Creager and Justin.

Figure 2 and 3 are nomographs and were prepared for an article on the Hardy Cross Method by D. R. Taylor [3]. Figure 4, also a nomograph, was prepared by J. R. Griffiths, of the U. S. Navy[4].

Values of the Coefficient "C"

Although the second and third charts are for definite values of the friction coefficient "C" in the Hazen-Williams Formula, the first chart by Creager may be used for any value of "C," if that value is known.

Recommended values of "C" for the Hazen-Williams Formula were given by Hazen and Williams in their book, "Hydraulic Tables"[5]. These values for straight line conduits are shown in Table 1.

TABLE 1

Table of C Values Cast Iron Pipe

Diameter Inches	Age in Years*						
	0	5	10	20	30	40	50
4	130	118	107	89	75	64	55
8	130	119	109	93	83	73	65
12	130	120	111	96	86	77	70
16	130	120	112	98	87	80	72
24	130	120	113	100	89	81	74
30	130	120	113	100	90	83	76
36	130	120	113	100	90	83	76
40	130	120	113	100	90	83	77
60	130	120	113	100	90	83	77

*Cleaning old pipe increases the C value.

Riveted Steel Pipe
- Light riveted steel pipe—
  - Avg. C for any age = 10 year C.I.P.
- Heavy riveted steel pipe—
  - Avg. C for any age = 20 year C.I.P.

Welded Steel Pipe
- Equivalent to 5 yr. or older C.I.P.

Wood Stave Pipe
- Best C = 145
- Probable Average C = 120
- Worst C = 110

Concrete Pipes and Pressure Tunnels
- Metal Forms
  - Best workmanship— C = 150
  - Probable workmanship—C = 140
  - Worst workmanship— C = 120
- Wood Form—Monolithic
  - Best workmanship— C = 130
  - Probable workmanship—C = 120
  - Worst workmanship— C = 90
- If Slimed
  - 20 points below Best
  - 15 points below Average
  - 10 points below Worst

In addition to the values in Table 1 the following values of the friction coefficient have been published by the National Tube Co.[6]

These values of the coefficient "C" are to be used in the Hazen-Williams formula for computing the loss of head due to friction in new well-laid pipe:

Kind of Pipe	Coefficient
"Duroline"	148*†
Wrought Steel	140
Small Brass and Copper	130
Cast Iron	130
Concrete	120
Wood Stave	120
Riveted Steel	110
Vitrified Pipe	110
Brick Sewers	100

*"Duroline" pipe is protected against internal corrosion and mounting friction losses by a cement base composition lining of a highly durable nature.—Ed.

†Approximately the same for cement lined pipe. —Ed.

It must be understood that these values depend upon the smoothness and regularity of the surfaces and are likely to vary in individual cases. In designing a pipe line it is customary to use somewhat lower coefficients than those above, to allow for variations due to local conditions, and for reduction of carrying capacity with age due to roughening of the inside surface, accumulation of corrosion products, and tuberculation. However, in case of cement or enamel lined pipe, the volume of flow remains practically unchanged over long periods of service due to the fact that rust tubercles do not form and the initially smooth inside surface is retained.

Useful Loss of Head Tables

D. R. Taylor[3] gives two tables on loss of head. The first (Table 2) gives values for use in the formula

$$S = RQ_m^{1.85}$$

where S = loss of head per 1000 ft.
R = resistance factor depending on size and smoothness of pipe.
Q_m = quantity of flow in gal. per min.

Values in the table are given as "k" values which are equal to 100,000 times the "R" value.

Table 3 gives "R" values when the flow quantity is expressed in mil. gal. per day, for the formula $S = RQ_1^{1.85}$

where S = loss of head per 100 ft. of pipe.
R = resistance factor.
Q_1 = quantity flow in mgd.

In Table 4 are listed pipe friction for various size pipes and velocities.[3]

Loss of Head for Valves and Fittings

The following discussion and its accompanying chart titled Friction Chart for Valves and Fittings have been taken from Crane Company's "Engineering Data on Flow of Fluids in Pipes"[1]

When the flow of a fluid in a pipe line is altered by some obstruction such as a valve or fitting, the velocity is changed, turbulence is magnified and a drop in pressure results. This pressure drop may be insignificant in long lines where it is very small in comparison to the total drop, but when the line is short the pressure drop through valves

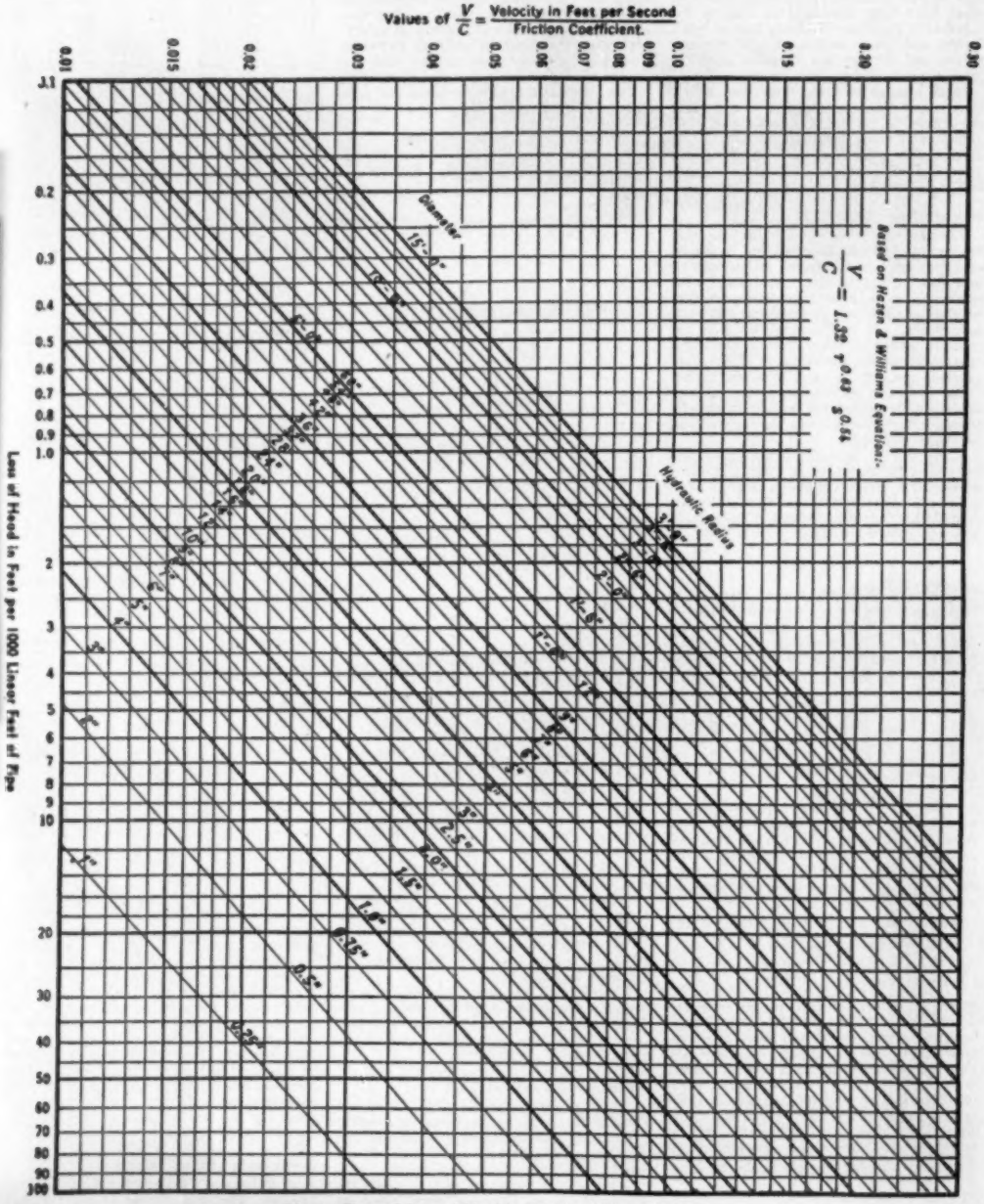
Values of V/C = Velocity in Feet per Second / Friction Coefficient.
Loss of Head in Feet per 1000 Linear Feet of Pipe
Diameter
Hydraulic Radius
Based on Hazen & Williams Equation:-
V/C = 1.32 r^0.63 s^0.54

Fig. 1—Chart of Loss of Head in Feet per 1000 ft. of Pipe

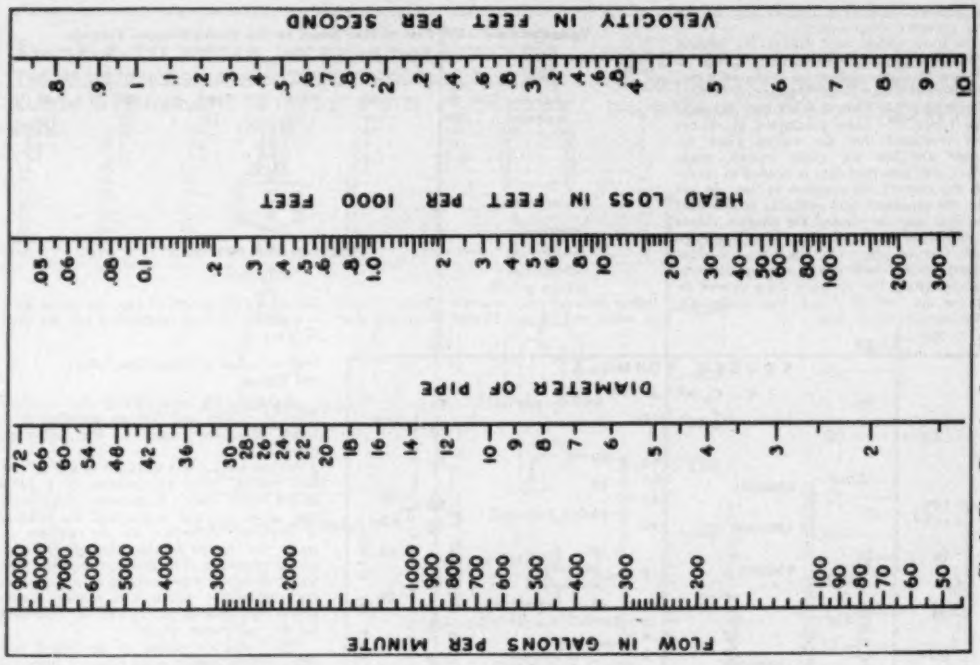

Fig. 3—Flow Chart for C = 120 (Hazen and Williams Formula)

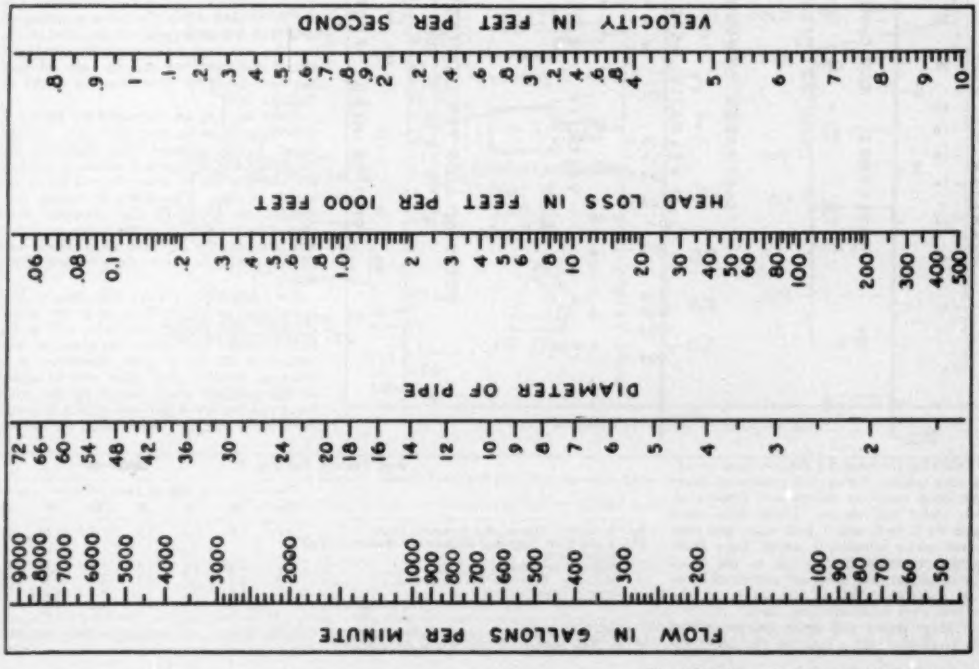

Fig. 2—Flow Chart for C = 100 (Hazen and Williams Formula)

and fittings becomes a major item in the total pressure drop valve.

The most widely used data on the subject of the resistance of valves and fittings to the flow of water and steam is the information given in Dean Foster's paper on "Effect of Fittings on Flow of Fluids Through Pipe Lines."[6] Tests conducted by others have indicated that the values given by Foster are low for globe valves, angle valves, etc., and that data is needed to establish the correct information to use. It has been the tendency, and probably is the most practical way, to present the friction values in terms of an equivalent length of the same size of pipe; i.e., the pressure drop caused by a 2-inch elbow is equivalent to approximately the pressure drop caused by five or six feet of 2-inch pipe under the same conditions of flow.

TABLE 2

Values of k for 1,000 Feet of Pipe Based on the Hazen-Williams Formula

Pipe Diameter, Inches	C = 90	100	110	120	130	140
4	300	248	208	117	153	133
6	41	33.7	28.4	24.2	20.9	18.2
8	10	8.4	7.0	6.0	5.2	4.5
10	3.4	2.8	2.4	2.0	1.7	1.5
12	1.5	1.2	1.0	.83	.71	.62
14	.66	.55	.46	.39	.34	.30
16	.35	.29	.24	.20	.18	.15
18	.20	.16	.14	.12	.10	.09
20	.12	.10	.08	.07	.06	.05
24	.049	.04	.03	.03	.02	.02
30	.016	.013	.011	.010	.008	.007
36	.0067	.0054	.0046	.0039	.0034	.0030

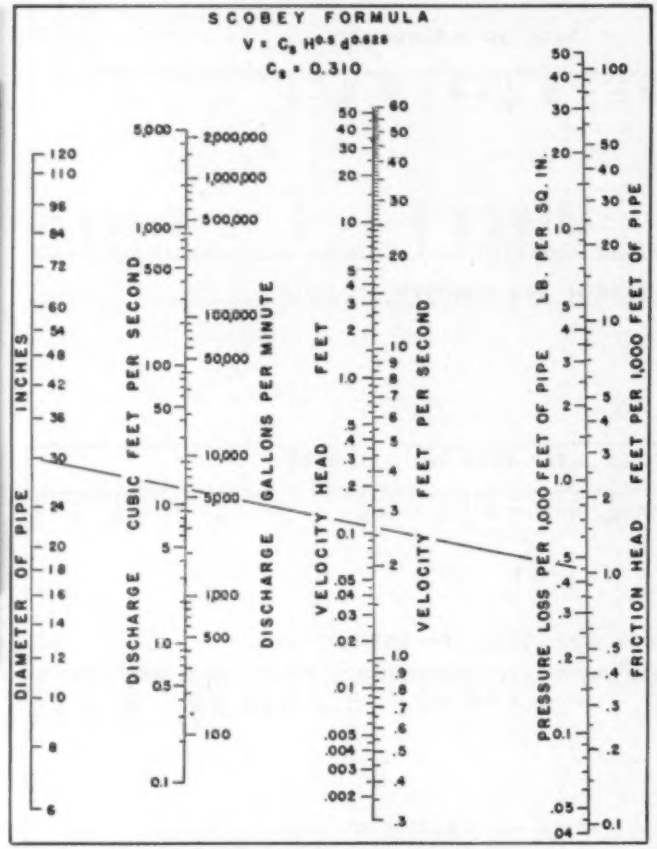
SCOBEY FORMULA
V = C_s H^0.5 d^0.625
C_s = 0.310
DIAMETER OF PIPE INCHES
DISCHARGE CUBIC FEET PER SECOND
DISCHARGE GALLONS PER MINUTE
VELOCITY HEAD FEET
VELOCITY FEET PER SECOND
PRESSURE LOSS PER 1,000 FEET OF PIPE LB. PER SQ. IN.
FRICTION HEAD FEET PER 1,000 FEET OF PIPE

Fig. 4—Flow of Water in Concrete Pipe

Realizing the need for definite data covering this subject, Crane Co. conducted pressure drop tests on valves and fittings on both water and steam. These tests were made on 2 inch and 6 inch sizes and conducted under conditions which were thoroughly investigated previous to the tests. The results of these tests are presented herewith together with a description of the method used in conducting them.

[*Note.*—Water and steam can be treated comparatively and a relation can be established between the relative friction values of water and steam. Foster has stated that the equivalent length of pipe for steam flow is about .8 of that established for the flow of water.]

Friction Losses of Water Line Valves and Fittings

The tests for determining the pressure drop of valves and fittings installed in a water line were made in the following manner:

A flow nozzle was installed in a 3 in. test line leading from the bottom of a 1,000 gallon water tank. A mercury manometer was set across this nozzle and the relation of mercury deflection to the gallons of water per minute flowing through the pipe was determined. The flow through the pipe was thereafter noted only in terms of mercury deflection which was readily transposed into gallons per minute by reference to the calibration chart.

The valve or fitting to be tested was placed in the line at some distance from the flow nozzle and the flow water through it was regulated by a throttling valve situated at the outlet of the line. The pressure drop was measured by means of a mercury manometer, or where the deflection was too great, by two sensitive low pressure gages, the leads of which were situated in the test line at a distance of ten pipe diameters (20 in.) from each end of the valve or fitting on test. The initial pressure at the inlet of the test line was kept constant at 80 pounds per square inch and the various rates of flow were produced by throttling the outlet of the test line.

After the data was obtained the means of presenting it in its best form was investigated. In any pressure drop tabulation, the values for the fittings and valves in the line are added to the pressure drop of the entire length of line. Therefore, it seemed reasonable to disregard the pressure drop caused by the length of the valve or fitting and just list the pressure drop which was added to the line due to the presence of the article.

For instance, if a valve 4 in. face to face is installed in a line 30 in. long, the actual pressure drop through the valve will be the total pressure drop minus the pressure drop caused by 26 in. of pipe. However, in a practical problem this value will be added to the pressure drop caused by the total length of the line which will give a pressure drop value slightly higher than the actual.

Age Factors For Fig. 5

	Age in Years						
	New	10	15	20	30	50	75
Fire Protection Mains—No Domestic Draft	0.7	0.9	1.0	1.1	1.4	1.8	2.3
Public and Fire Protection Mains with Domestic Draft							
Surface Water							
Slight Tuberculation	0.7	0.9	1.0	1.1	1.4	1.8	2.3
Moderate Tuberculation	0.7	1.2	1.7	2.1	2.9	3.5	3.9
Severe Tuberculation	0.7	1.6	2.4	3.1	4.3	5.2	5.5
Well Water	0.7	1.6	2.4	3.1	4.5	5.3	5.5

These age factors for cast-iron mains are adapted from the results of an investigation by a committee of the New England Water Works Association[31].

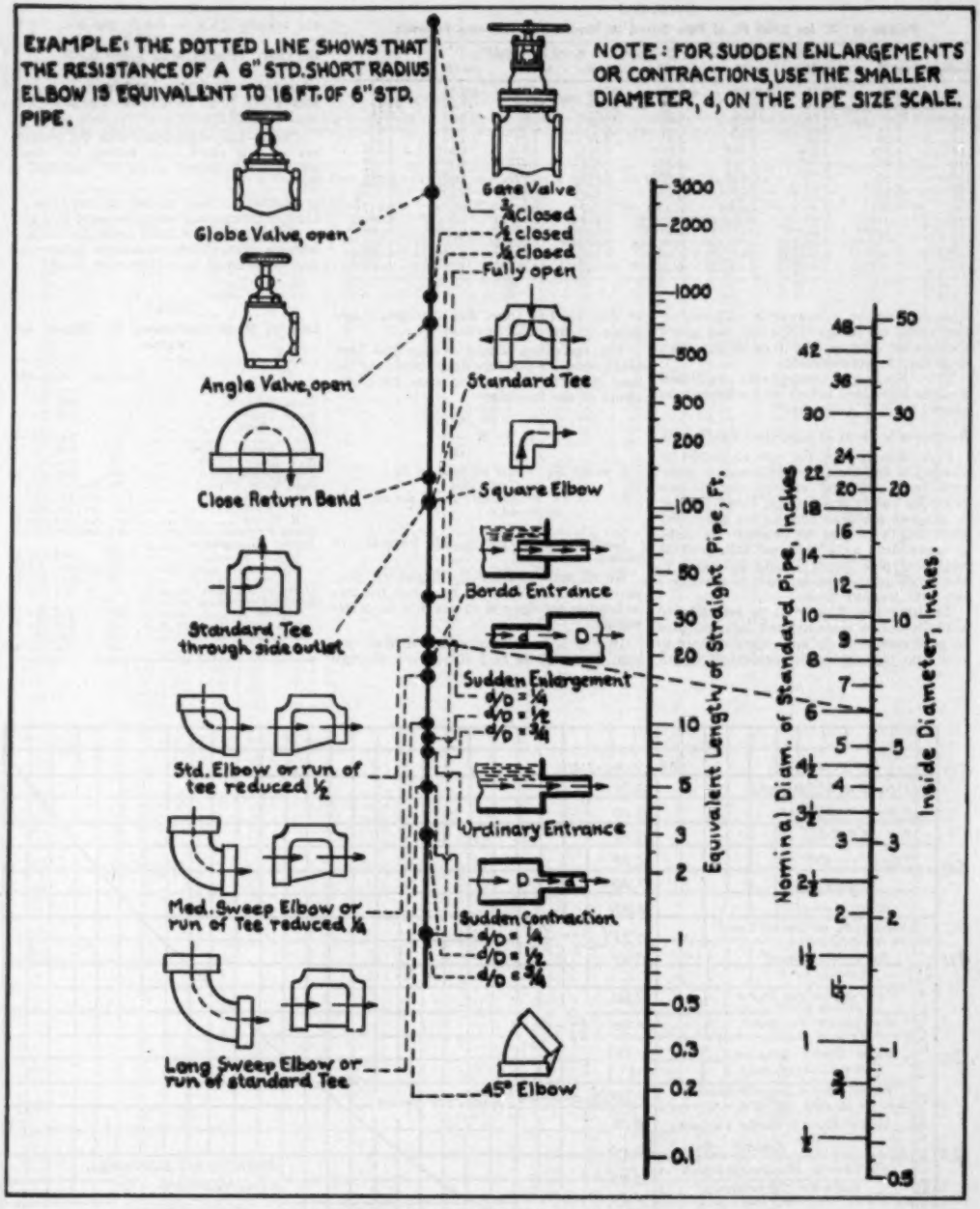

Fig. 5—Friction Chart for Valves and Fittings
*(For Converting These Units Into Equivalent Added Length of Pipe)**

*Note: These equivalents, in terms of length of pipe to be added in computations, were derived for steel pipe in good condition. In applying the chart to cast-iron pipe divide the equivalent length of steel pipe by 1.64 times the most appropriate age factor found in Table 5 of "Age Factors" for C.I. mains.

TABLE 3

Values of "R" for 1,000 Ft. of Pipe Based on Hazen and Williams Formula

d—Inches	Head Loss in Ft.: S = R x Q^1.85 per 1,000 ft. (Q in m.g.d.) c = 70	c = 80	c = 90	c = 100	c = 110	c = 120	c = 130	c = 140
4	860.69	672.11	540.67	444.91	373.00	317.53	273.83	238.76
6	119.44	93.30	75.03	61.74	51.76	44.06	38.00	33.13
8	29.42	22.98	18.48	15.21	12.75	10.85	9.36	8.16
10	9.93	7.75	6.24	5.13	4.30	3.66	3.16	2.75
12	4.08	3.19	2.57	2.11	1.77	1.51	1.30	1.13
14	1.925	1.504	1.209	0.995	0.834	0.710	0.612	0.534
16	1.002	0.787	0.633	0.521	0.437	0.372	0.320	0.279
18	0.567	0.443	0.356	0.293	0.246	0.209	0.180	0.157
20	0.3390	0.2648	0.2130	0.1753	0.1469	0.1251	0.1079	0.0941
24	0.1396	0.1091	0.0877	0.0722	0.0605	0.0518	0.0444	0.0378
30	0.0471	0.0368	0.0296	0.0244	0.0204	0.0174	0.0150	0.0151
36	0.01939	0.01514	0.01218	0.01002	0.00840	0.00715	0.00617	0.00528
42	0.00915	0.00715	0.00575	0.00473	0.00397	0.00338	0.00291	0.00254
48	0.004774	0.003729	0.002999	0.002468	0.002057	0.001761	0.001519	0.001324
60	0.001611	0.001258	0.001012	0.000833	0.000698	0.000594	0.000513	0.000447
66	0.001013	0.000791	0.000636	0.000524	0.000439	0.000374	0.000322	0.000281

This may not be so noticeable with one or two valves or fittings in the line, but where the number runs up into 10 or 20 the added drop may be considerable.

This "No-length" concept was established and has been used before with reference to elbows by F. E. Giesecke.[3]

Resistance in Terms of Equivalent Pipe Length

From data given in the tests conducted by Crane Co. and also from information gathered from authentic sources, the friction chart for valves and fittings, shown in Fig. 5, has been prepared which gives the equivalent length of pipe to produce the same pressure drop as a valve or fitting. This additional pipe length should be added to the length of the line in order to determine the total pressure drop.

In using Fig. 5, it must be remembered that the values were derived for steel pipe in good condition. In applying the chart to cast iron pipe divide the equivalent length of steel by 1.64 times the appropriate age factor in the table opposite Fig. 5.

The equivalent length of pipe has been based upon the pressure drop values for the flow of water in pipes and upon the coefficients of the formula.

$$H_l = K\frac{V^2}{2g}$$

where H_l = Loss of head in ft.
K = Coefficient
V = Velocity in ft. per sec.
$2g$ = 64.4

Coefficients for use in this formula are shown in Table 5.

Burns and McDonnell, Engineers, prepared the chart (Fig. 6) by which the loss in head in fittings and valves may be determined.

In Fig. 6, to determine loss of head—assum flow (Q) to be 5 ft. per sec. through a fitting of 12 in. diameter. From Q = AV, the velocity (V) = 6.4 ft. per sec. From the chart, velocity head $\frac{V^2}{2g}$ = 0.7 ft.

Applied to 90 degree bend head loss is 0.25 × 0.7 = 0.18 ft. For a tee 1.25 × .7 = 0.87 ft.

(Note—Correspondence with the producers of this chart cites values for check valves far in excess of the 0.5 indicated.—*Ed.*)

Another method of determining loss of head in fittings and valves is given in Table 6 with approximate head losses for various fittings. Exact losses cannot be determined due to variation in construction details.

TABLE 5

Loss of Head Coefficients for Fittings and Valves

Type	Coefficient	Authority
Globe Valves	10	Ref. No. 7
Angle Valve	5	Ref. No. 7
Return Bend	2.2	
Tee	1.8	Ref. No. 9
Short Radius Elbow	.9	Ref. No. 9
Med. Radius Elbow	.75	Ref. No. 7
Long Radius Elbow	.60	Ref. No. 10
Gate Valve (Open)	.19	Av. Ref. No. 11
¾ Closed	1.15	Av. Ref. No. 11
½ Closed	5.6	Av. Ref. No. 11
¼ Closed	24.0	Av. Ref. No. 11
Borda Entrance	.83	Av. Ref. No. 12
Sudden Enlargement		
d/D — ⅛	.92	Ref. No. 12
d/D — ½	.56	Ref. No. 12
d/D — ¾	.19	Ref. No. 12
Ordinary Entrance	.5	Ref. No. 12
Sudden Contraction		
d/D = ¾	.42	Ref. No. 12
d/D = ½	.33	Ref. No. 12
d/D = ¼	.19	Ref. No. 12
45° Elbow	.42	Ref. No. 10

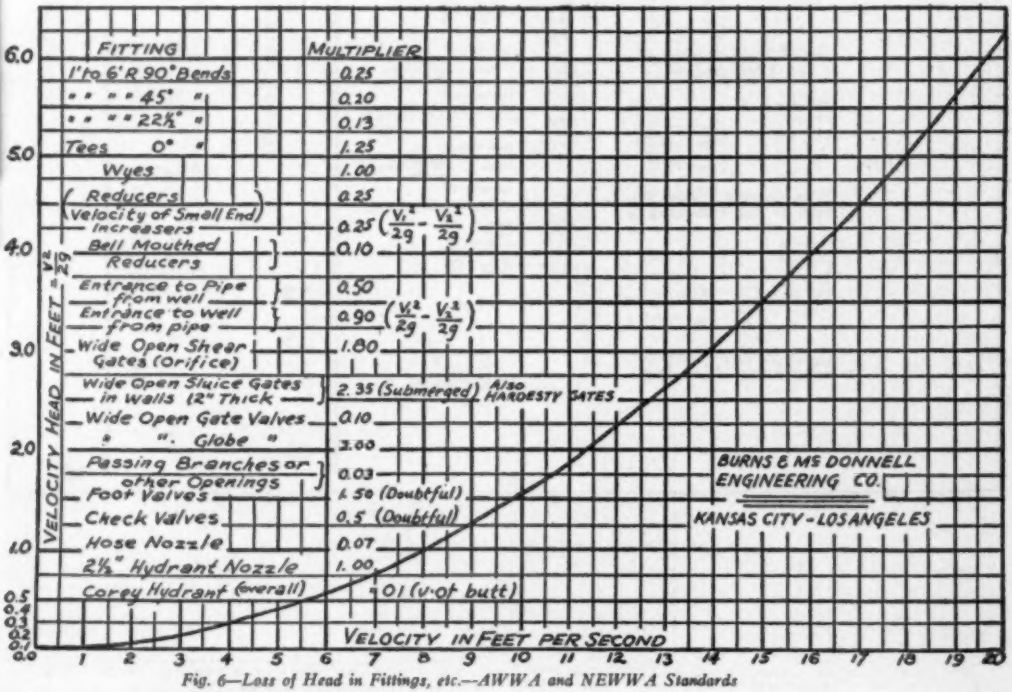

Fig. 6—Loss of Head in Fittings, etc.—AWWA and NEWWA Standards

TABLE 4

Friction of Water in Pipes

The pipe frictions shown in the following tables are taken by permission from the more complete copyright tables by Williams and Hazen, published by John Wiley & Sons, and these values are recommended for use in figuring pipe frictions.

Loss of Head in Feet Due to Friction, per 100 feet of 15 year old Ordinary Iron Pipe

U.S. Gal's per Min.	1" Pipe		1¼" Pipe		1½" Pipe		2" Pipe		2½" Pipe		3" Pipe	
	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.
10	3.72	11.7	2.14	3.05	1.57	1.43	1.02	0.50	0.65	0.17	0.45	0.07
15	5.60	25.0	3.2	6.50	2.36	3.0	1.53	1.0	0.98	0.36	0.68	0.15
20	7.44	42.0	4.29	11.1	3.15	5.2	2.04	1.62	1.31	0.61	0.91	0.25
25	9.30	64.0	5.36	16.6	3.94	7.8	2.55	2.73	1.63	0.92	1.13	0.38
30	11.15	89.0	6.43	23.5	4.72	11.0	3.06	3.84	1.96	1.29	1.36	0.54
35	13.02	119.0	7.51	31.2	5.51	14.7	3.57	5.1	2.29	1.72	1.59	0.71
40	14.88	152.0	8.58	40.0	6.3	18.8	4.08	6.6	2.61	2.20	1.82	0.91
45	.....	.....	9.65	50	7.08	23.3	4.60	8.2	2.94	2.80	2.05	1.15
50	.....	.....	10.72	60	7.87	28.4	5.11	9.9	3.27	3.32	2.27	1.38
70	.....	.....	15.01	113	11.02	53.0	7.15	18.4	4.58	6.2	3.18	2.57
90	.....	.....	.....	.....	14.17	84.0	9.19	29.4	5.88	9.8	4.09	4.08
100	.....	.....	.....	.....	15.74	102.0	10.21	35.8	6.54	12.0	4.54	4.96
120	.....	.....	.....	.....	18.89	143.0	12.25	50.0	7.84	16.8	5.45	7.0
140	.....	.....	.....	.....	22.04	190.0	14.30	67.0	9.15	22.3	6.35	9.2
160	.....	.....	.....	.....	.....	.....	16.34	86.0	10.46	29.0	7.26	11.8
180	.....	.....	.....	.....	.....	.....	18.38	107.0	11.76	35.7	8.17	14.8
200	.....	.....	.....	.....	.....	.....	20.42	129.0	13.07	43.1	9.08	17.8
220	.....	.....	.....	.....	.....	.....	22.47	154.0	14.38	52.0	9.99	21.3
240	.....	.....	.....	.....	.....	.....	24.51	182.0	15.69	61.0	10.89	25.1
260	.....	.....	.....	.....	.....	.....	26.55	211.0	16.99	70.0	11.80	29.1
280	.....	.....	.....	.....	.....	.....	.....	.....	18.30	81.0	12.71	33.4
300	.....	.....	.....	.....	.....	.....	.....	.....	19.61	92.0	13.62	38.0

U. S. Gal's per Min.	4" Pipe		5" Pipe		6" Pipe		8" Pipe		10" Pipe		12" Pipe		14" Pipe		15" Pipe		16" Pipe		20" Pipe		24" Pipe	
	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.
40	1.02	0.22	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
45	1.17	0.28	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
50	1.28	0.34	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
70	1.79	0.63	1.14	0.21	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
75	1.92	0.73	1.22	0.24	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
100	2.55	1.22	1.63	0.41	1.14	0.16	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
120	3.06	1.71	1.96	0.58	1.42	0.25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
125	3.19	1.86	2.04	0.64	1.48	0.28	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
150	3.84	2.85	2.45	0.88	1.71	0.32	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
175	4.45	3.44	2.86	1.18	2.00	0.48	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
200	5.11	4.49	3.27	1.48	2.28	0.62	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
225	5.77	5.45	3.67	1.86	2.57	0.74	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
250	6.40	6.72	4.08	2.24	2.80	0.92	1.60	0.22	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
270	6.90	7.70	4.42	2.60	3.03	1.13	1.70	0.25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
275	7.03	7.99	4.50	2.72	3.06	1.15	1.73	0.27	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
300	7.66	9.30	4.90	3.14	3.40	1.29	1.90	0.32	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
350	8.90	12.32	5.72	4.19	3.98	1.75	2.20	0.42	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
400	10.21	16.00	6.54	5.40	4.54	2.21	2.60	0.54	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
450	11.50	19.80	7.35	6.70	5.12	2.65	2.92	0.68	1.80	0.21	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
470	12.10	22.40	7.70	7.22	5.49	2.90	3.07	0.75	1.92	0.24	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
475	12.20	22.96	7.76	7.42	5.55	2.95	3.10	0.76	1.94	0.25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
500	12.77	24.00	8.17	8.12	5.60	3.20	3.20	0.82	2.04	0.28	1.42	0.11	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
550	.....	.....	8.99	9.60	6.16	3.93	3.52	0.97	2.25	0.33	1.57	0.14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
600	.....	.....	9.80	11.30	6.72	4.70	3.84	1.14	2.46	0.39	1.71	0.15	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
650	.....	.....	10.62	13.20	7.28	5.40	4.16	1.34	2.66	0.46	1.85	0.19	1.37	0.09	.....	.....	.....	.....	.....	.....	.....	.....
700	.....	.....	11.44	15.10	7.84	6.20	4.46	1.54	2.86	0.52	2.00	0.22	1.47	0.10	.....	.....	.....	.....	.....	.....	.....	.....
750	.....	.....	12.26	17.20	8.50	7.00	4.80	1.74	3.06	0.59	2.13	0.24	1.58	0.11	.....	.....	.....	.....	.....	.....	.....	.....
800	.....	.....	.....	.....	9.08	8.00	5.12	1.97	3.28	0.67	2.27	0.27	1.68	0.13	.....	.....	.....	.....	.....	.....	.....	.....
850	.....	.....	.....	.....	9.58	8.95	5.48	2.28	3.48	0.75	2.41	0.31	1.79	0.14	.....	.....	.....	.....	.....	.....	.....	.....
900	.....	.....	.....	.....	10.30	10.11	5.75	2.46	3.68	0.83	2.56	0.34	1.89	0.16	.....	.....	.....	.....	.....	.....	.....	.....
950	.....	.....	.....	.....	10.72	10.80	6.06	2.87	3.88	0.91	2.70	0.38	2.00	0.18	1.73	0.12	.....	.....	.....	.....	.....	.....
1000	.....	.....	.....	.....	11.32	12.04	6.40	3.02	4.08	1.01	2.84	0.41	2.10	0.19	1.82	0.14	.....	.....	.....	.....	.....	.....
1050	.....	.....	.....	.....	11.90	13.30	6.70	3.21	4.29	1.09	2.98	0.44	2.20	0.22	1.91	0.16	.....	.....	.....	.....	.....	.....
1100	.....	.....	.....	.....	12.50	14.31	7.03	3.51	4.50	1.20	3.13	0.49	2.31	0.23	2.00	0.17	.....	.....	.....	.....	.....	.....
1150	.....	.....	.....	.....	12.95	15.00	7.35	3.84	4.71	1.34	3.27	0.53	2.42	0.25	2.09	0.18	.....	.....	.....	.....	.....	.....
1200	.....	.....	.....	.....	13.52	16.69	7.67	4.15	4.91	1.46	3.41	0.57	2.52	0.26	2.18	0.19	.....	.....	.....	.....	.....	.....
1250	.....	.....	.....	.....	14.10	18.50	8.00	4.45	5.11	1.51	3.55	0.62	2.63	0.29	2.28	0.20	1.99	0.15	.....	.....	.....	.....
1500	.....	.....	.....	.....	.....	.....	9.60	6.27	6.10	2.09	4.20	0.85	3.15	0.39	2.73	0.28	2.39	0.21	.....	.....	.....	.....
2000	.....	.....	.....	.....	.....	.....	12.70	10.71	8.10	3.65	5.60	1.43	4.20	0.66	3.64	0.54	3.19	0.39	.....	.....	1.42	0.08
2500	.....	.....	.....	.....	.....	.....	.....	.....	10.10	5.33	7.00	2.28	5.25	1.01	4.55	0.72	3.99	0.56	.....	.....	1.77	0.07
3000	.....	.....	.....	.....	.....	.....	.....	.....	12.10	7.80	8.40	3.15	6.30	1.47	5.46	1.12	4.79	0.80	3.08	0.27	2.12	0.10
3500	.....	.....	.....	.....	.....	.....	.....	.....	14.10	10.08	9.80	4.10	7.35	1.81	6.37	1.43	5.59	1.04	3.59	0.35	2.49	0.14
4000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	11.35	5.32	8.40	2.47	7.28	1.85	6.38	1.34	4.10	0.45	2.85	0.18
4200	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	11.93	6.00	8.82	2.80	7.64	2.08	6.72	1.45	4.32	0.50	.....	.....
4500	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	12.78	6.90	9.45	3.22	8.19	2.33	7.20	1.65	4.62	0.56	3.26	0.22
5000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	14.20	8.40	10.50	3.92	9.10	2.78	7.96	2.02	5.13	0.68	3.54	0.27
5500	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	11.55	4.65	10.01	3.30	8.78	2.39	5.64	0.82	3.90	0.33
6000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	12.60	5.50	10.92	3.90	9.56	2.60	6.15	0.96	4.25	0.38
6500	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	13.65	6.45	11.83	4.55	10.36	3.32	6.66	1.06	4.61	0.45
7000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	14.70	7.15	12.74	5.08	11.12	3.68	7.18	1.28	4.97	0.52
7200	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	13.10	5.45	11.50	3.96	7.38	1.35	.....	.....
7500	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	13.65	5.90	11.95	4.28	7.66	1.45	5.32	0.59
8000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	8.17	1.63	5.68	0.66
8500	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	8.68	1.83	6.03	0.74
9000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	9.20	2.04	6.35	0.81
9500	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	9.70	2.23	6.74	0.91
10000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10.40	2.53	7.07	0.98

Vel.—Velocity ft. per second. Fric.—Friction head in feet.

TABLE 7

Values for Determining Head Losses for Fittings

Diameter of fittings	1	1½	2	2½	3	4	5	6	7	Inches
Constant	2.5 8	3.75 9	5 10	6.25 11	7.5 12	10 15	12.5 16	15 18	17.5 20	Constant Inches
	20	22.5	25	27.5	30	37.5	40	45	50	Constant

Multipliers for Different Fittings

45° Ell	0.26	*Angle Globe Valve	5.0	Reciprocating piston	20.0
90° Ell	1.0	*Check Valve	3.0	Turbine wheel type (Double flow balanced)	8.3
Tee	2.0	Water Meters:		Venturi Meters:	
*Gate Valve	0.37	Disk or wobble plate type	9.0	Ratio of $d_2/d_1 = 0.5$	2.66
*Globe Valve	3.33	Rotary (disk or star shape, as piston)	13.3	Ratio of $d_2/d_1 = 0.4$	5.66

*Multipliers are for valves operating wide open.

In Table 6 under each size fitting is a constant which, multiplied by the multiplier for each kind of fitting in the pipe line, will give the additional length in feet to be added to the actual length of discharge pipe or pipe line. Take, for example, a 10-inch pipe line 300-feet long with 2-90° ells, 1-gate valve, 1-check valve and a venturi meter having a ratio of $d_2/d_1 = 0.5$. The additional length for head loss in these fittings is made up as follows: 2-90° ells 25-feet each, 1-gate valve 9-feet, 1-check valve 75-feet, 1-venturi meter 66-feet, making a total of 200-feet additional which must be added to the 300-feet actual length, or the equivalent of 500-feet of new 10-inch pipe line upon which the friction head loss must be figured in order to arrive at the total loss in the pipe line and fittings.

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EQUATION OF PIPES

It is frequently desired to know what number of pipes of a given size are equal in carrying capacity to one pipe of a larger size. At the same velocity of flow the volume delivered by two pipes of different sizes is proportional to the squares of their diameters; thus one 4-inch pipe will deliver the same volume as four 2-inch pipes. With the same head, however, the velocity is less in the smaller pipe, and the volume delivered varies about as the square root of the fifth power. This table is calculated on this basis. The figures opposite the intersection of any two sizes is the number of the smaller-sized pipes required to equal one of the larger; thus one 4-inch equals 5.7 two-inch.

Dia. in.	1	2	3	4	5	6	7	8	10	12	14	16	18	20	24	30	36
2	5.7	1.															
3	15.6	2.8	1.														
4	32.	5.7	2.1	1.													
5	55.9	9.9	3.6	1.7	1.												
6	88.2	15.6	5.7	2.8	1.6	1.											
7	130.	22.9	8.3	4.1	2.3	1.5	1.										
8	181.	32.	11.7	5.7	3.2	2.1	1.4	1.									
10	316.	55.9	20.3	9.9	5.7	3.6	2.4	1.7	1.								
11	401.	70.9	25.	12.5	7.2	4.6	3.1	2.2	1.3								
12	499.	88.2	32.	15.6	8.9	5.7	3.8	2.8	1.6	1.							
13	609.	108.	39.1	19.	10.9	7.1	4.7	3.4	1.9	1.2							
14	733.	130.	47.	22.9	13.1	8.3	5.7	4.1	2.3	1.5	1.						
15	787.	154.	55.9	27.2	15.6	9.9	6.7	4.8	2.8	1.7	1.2						
16		181.	65.7	32.	18.3	11.7	7.9	5.7	3.2	2.1	1.4	1.					
17		211.	76.4	37.2	21.3	13.5	9.2	6.6	3.8	2.4	1.6	1.2					
18		243.	88.2	43.	24.6	15.6	10.6	7.6	4.3	2.8	1.9	1.3	1.				
19		278.	101.	49.1	28.1	17.8	12.1	8.7	4.8	3.2	2.1	1.5	1.1				
20		316.	115.	55.9	32.	20.3	13.8	9.9	5.7	3.6	2.4	1.7	1.3	1.			
22		401.	146.	70.9	40.6	25.7	17.5	12.5	7.2	4.6	3.1	2.2	1.7	1.3			
24		499.	181.	88.2	50.5	32.	21.8	15.6	8.9	5.7	3.8	2.8	2.1	1.6	1.		
30								27.2	15.6	10.0	6.7	4.8	3.6	2.8	1.75	1.0	
36									24.6	15.6	10.6	7.6	5.7	4.3	2.76	1.6	1.0

METERS · GAGES · CONTROLLERS
for Sewage Treatment and Water Supply

BAILEY METER COMPANY

1072 IVANHOE RD., CLEVELAND, OHIO
Bailey Meter Company Limited, Montreal, Canada

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STANDARD BAILEY REGISTERS

Standard Bailey Registers measure flow of sewage, industrial wastes, sludge, dirty water, or other liquids in open channels or in pipe lines. They also measure air flow, pH, liquid level in open and closed tanks and reservoirs, and other factors.

• • • **FOR OPEN CHANNELS—The Bailey Flume or Weir Meter** is simple and accurate. As shown in the illustration (right), it consists of a single float connected by a flexible cable to a sturdy indicating, recording and integrating mechanism which may be mounted on a panel board, a wall, or a column. It is adaptable to all open channel metering devices including flumes, weirs and nozzles and can be adjusted to any required operating range. Remote location is possible through use of a Bailey Telemeter, (see below). **Ask for Bulletin 62**

• • • **FOR PIPE LINES—The Bailey Open Float Type Meter** measures flow of sewage, sludge, dirty water, or other liquids in pipe lines using Venturi Tubes, flow nozzles, or eccentric orifices. It operates through a differential gearing and cam mechanism from floats which rest on the liquid surfaces in float tubes.

The Bailey Fluid Meter accurately measures flow of steam, liquids, and gases in pipe lines at high or low pressures. A Venturi Tube, flow nozzle, or orifice, is used as the differential producing device and the meter indicates, records and integrates on a Standard Bailey Register. This meter may also provide records of pressure, temperature or liquid level on the same chart. **Ask for Bulletin 301 B**

• • • **FOR LIQUID LEVEL**—Bailey Registers may be used in measuring liquid level in open tanks and reservoirs. Three methods are available to meet any requirement.

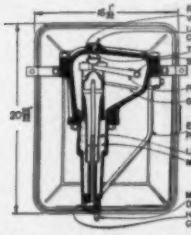
Open Float Method—(for location above liquid level). Has a minimum range of 0 to 5 inches of water and a maximum range of 0 to 60 feet of water.

Static Pressure Method—(for location below liquid level). Two types are available; mercury U-tube and float for minimum range of 0 to 50 inches of water, and maximum of 0 to 150 feet of water, and a helical coil for minimum range of 0 to 120 feet of water and maximum of 0 to 600 feet of water.

Bubbler System—For measuring level or specific gravity of corrosive liquids and of liquids with solids in suspension. **For information on Bailey Level Recorders ask for Bulletin #17-C**

• • • **FOR AIR FLOW—Bailey Air Meters** measure Air Flow in main lines and in individual lines to aeration tanks. The register used is similar in appearance to the Ledoux bell type (left) and the flow mechanism is designed to operate on a maximum differential pressure of eight inches of water. **Ask for Bulletin 301 B**

Air Flow from a rotary positive type blower can be measured accurately with a Bailey Electronic Type Recorder. Blower Shaft speed, measured by a tachometer is recorded in terms of Air Flow.

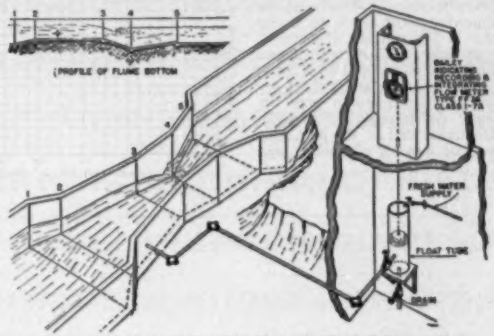


Ledoux Bell Flow Mechanism

BAILEY CONTROLLERS

Bailey Controllers utilize standard Bailey Instruments as the measurement source for automatic control of factors such as flow, ratio, pressure and liquid level. They operate by compressed air and are styled to match other Bailey Gages and Registers.

Bailey Control is fully automatic, dependable and exceptionally flexible. **Explained in Bulletin 17-C**



Typical installation of Bailey Flow Meter for Parshall Venturi Flume

pH RECORDER

The Bailey Electronic pH Recorder accurately measures and, if desired, controls hydrogen ion concentration in a solution. The indicating and recording instrument is similar in appearance to a Standard Bailey Register. **Described in Bulletin 234**

Bailey Recorder—Controller

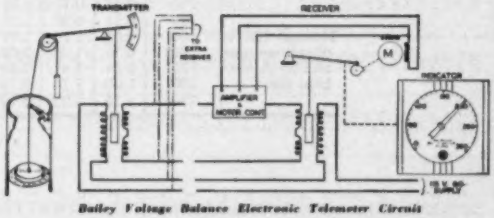
BAILEY TELEMETER

The Bailey Voltage Balance Electronic Telemeter is a quick, accurate means of transmitting position over distances. The measure of any factor which can be made to move the core of a small solenoid transformer may be indicated or recorded at a distant receiver. Multiple receivers may be connected to one transmitter. Several flow measurements can be totalized.

Bailey Large Dial Indicator

LARGE DIAL INDICATOR

Indicators containing the telemeter circuit receiving mechanism may be single or double face and may have 18, 24, or 30-inch dials. Numerals and indicating pointer are large for easy reading. **Ask for Bulletin 17-C**



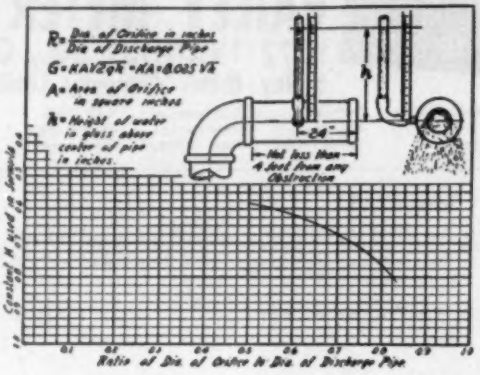
Bailey Voltage Balance Electronic Telemeter Circuit

MEASURING FLOWS BY THE ORIFICE METHOD

The orifice method is a simple way to measure flow of water from a pipe discharging horizontally into the open air. The sketch shows the general arrangement.

A plate or cap is affixed to the end of the pipe with the circular orifice in the exact center of the pipe. The size of orifice should be from one-half to three-quarters of the size of the pipe, but must be of such size that it will run full of water.

A hole for ⅛-in. pipe should be drilled and tapped 24 in. back from the orifice and a short ⅛-in. nipple screwed in until the inner end is exactly flush with the inner wall of the pipe. One end of a piece of rubber hose


R= Dia. of Orifice in inches / Dia. of Discharge Pipe
G=KA√2gh =KA×8.025√h
A= Area of Orifice in square inches
h= Height of water in glass above center of pipe in inches.
24"
Not less than 4 feet from any Obstruction
Constant K used in formula
Ratio of Dia. of Orifice to Dia. of Discharge Pipe

is slipped over the end of the nipple and the other end over a glass tube, which should be supported in a vertical position.

Ratio R is the diameter of the orifice divided by the inside diameter of the pipe, and the proper value of K is found from the curve. In the formula A is figured as the area of the orifice in square inches, G = 32.2, and H is read as the height in inches of the water in the glass tube above the center of the pipe. Gallons per minute (g) then can be figured.

For convenience when determining capacities during pumping tests, the accompanying table for various orifices commonly employed will prove useful.

FLOW OF WATER IN HOUSE SERVICE PIPES

(To find the discharge in gallons, multiply by 7.48)

Condition of Discharge	Pressure in Main Pounds per Square Inch	Discharge in Cubic Feet per Minute from the Pipe								
		Nominal Diameters of Iron or Lead Service Pipe in Inches								
		½	⅝	¾	1	1½	2	3	4	6
Through 35 ft. of service pipe; no back-pressure.	30	1.10	1.92	3.01	6.13	16.58	33.34	88.16	173.85	444.63
	40	1.27	2.22	3.48	7.08	19.14	38.50	101.80	200.75	513.42
	50	1.42	2.48	3.89	7.92	21.40	43.04	113.82	224.44	574.02
	60	1.56	2.71	4.26	8.67	23.44	47.15	124.68	245.87	628.81
	75	1.74	3.03	4.77	9.70	26.21	52.71	139.39	274.89	702.03
	100	2.01	3.50	5.50	11.20	30.27	60.87	160.96	317.41	811.79
	130	2.29	3.99	6.28	12.77	34.51	69.40	183.52	361.91	925.58
Through 100 ft. of service pipe; no back-pressure.	30	0.66	1.16	1.84	3.78	10.40	21.30	58.19	118.13	317.23
	40	0.77	1.34	2.12	4.36	12.01	24.59	67.19	136.41	366.30
	50	0.86	1.50	2.37	4.88	13.43	27.50	75.13	152.51	409.54
	60	0.94	1.65	2.60	5.34	14.71	30.12	82.30	167.06	448.63
	75	1.05	1.84	2.91	5.97	16.45	33.68	92.01	186.78	501.58
	100	1.22	2.13	3.36	6.90	18.99	38.89	106.24	215 68	579.18
	130	1.39	2.42	3.83	7.86	21.66	44.34	121.14	245.91	660.36
Through 100 ft. of service pipe and 15-ft. vertical rise.	30	0.55	0.96	1.52	3.11	8.57	17.55	47.90	97.17	260.56
	40	0.66	1.15	1.81	3.72	10.24	20.95	57.20	116.01	311.09
	50	0.75	1.31	2.06	4.24	11.67	23.87	65.18	132.20	?54.49
	60	0.83	1.45	2.29	4.70	12.94	26.48	72.28	146.61	398.13
	75	0.94	1.64	2.59	5.32	14.64	29.96	81.79	165.90	444.85
	100	1.10	1.92	3.02	6.21	17.10	35.00	95.55	193.82	519.72
	130	1.26	2.20	3.48	7.14	19.66	40.23	109.82	222.75	597.31
Through 100 ft. of service pipe and 30-ft. vertical rise.	30	0.44	0.77	1.22	2.50	6.80	14.11	38.63	78.54	211.54
	40	0.55	0.97	1.53	3.15	8.68	17.79	48.68	98.98	266.59
	50	0.65	1.14	1.79	3.69	10.16	20.82	56.98	115.87	312.08
	60	0.73	1.28	2.02	4.15	11.45	23.47	64.22	130.59	351.73
	75	0.84	1.47	2.32	4.77	13.15	26.95	73.76	149.99	403.98
	100	1.00	1.74	2.75	5.65	15.58	31.93	87.38	177.67	478.55
	130	1.15	2.02	3.19	6.55	18.07	37.02	101.33	206.04	554.96

ORIFICE TABLE FOR DETERMINING WATER FLOW

Compiled by the Engineering Department of Layne and Bowler, Inc., from original calibrations made in Hydraulic Laboratories at Purdue University.

Head in Inches	3" Orifice		4" Orifice		5" Orifice		6" Orifice		7" Orifice	8" Orifice	Head in Inches
	4 in. Pipe	6 in. Pipe	6 in. Pipe	8 in. Pipe	6 in. Pipe	8 in. Pipe	8 in. Pipe	10 in. Pipe	10 in. Pipe	10 in. Pipe	
5	100	76	145	140	280	220	380	320			5
5.5	104	79	153	145	293	230	394	333			5.5
6	108	82	160	150	305	240	408	345			6
6.5	111	85	167	155	316	250	421	358			6.5
7	115	88	172	160	328	260	433	370			7
7.5	119	91	179	165	339	270	446	383			7.5
8	122	94	185	170	350	280	458	395	600	935	8
8.5	125	96	190	175	361	289	471	408	617	963	8.5
9	128	99	195	180	372	298	483	420	633	992	9
9.5	130	102	200	185	383	307	495	433	650	1016	9.5
10	133	104	205	190	393	316	508	445	666	1040	10
10.5	137	107	210	195	402	324	521	458	682	1060	10.5
11	140	109	215	200	412	330	533	470	698	1080	11
11.5	143	111	220	204	421	338	545	480	713	1100	11.5
12	146	114	225	208	430	346	556	490	728	1120	12
12.5	149	116	230	212	439	354	567	500	743	1139	12.5
13	151	118	234	216	448	362	578	510	757	1158	13
13.5	154	121	239	219	457	369	589	520	771	1176	13.5
14	157	123	243	224	465	376	599	530	785	1194	14
14.5	159	126	247	227	473	383	609	540	799	1212	14.5
15	162	128	250	231	480	390	618	550	812	1230	15
15.5	164	130	254	234	488	396	627	559	825	1248	15.5
16	167	132	257	238	495	402	636	568	838	1266	16
16.5	170	134	261	241	503	408	645	577	851	1284	16.5
17	172	136	264	245	510	414	654	586	863	1302	17
17.5	175	138	268	249	517	420	663	595	875	1319	17.5
18	178	140	271	252	524	426	672	604	887	1336	18
18.5	180	142	275	256	530	432	681	612	899	1353	18.5
19	183	144	278	259	536	438	690	620	910	1370	19
19.5	185	146	282	263	542	444	699	628	922	1387	19.5
20	187	148	285	266	548	449	708	636	933	1404	20
20.5	190	150	289	270	554	455	717	647	945	1421	20.5
21	192	152	292	273	560	460	726	650	956	1438	21
21.5	195	154	295	275	566	465	735	657	968	1455	21.5
22	197	156	299	279	572	470	744	664	979	1471	22
22.5	199	158	302	282	578	475	752	671	990	1486	22.5
23	201	160	305	285	584	479	760	678	1001	1500	23
23.5	203	162	307	288	590	484	768	685	1012	1515	23.5
24	205	164	310	291	596	488	776	692	1022	1529	24
24.5	207	165	314	294	602	492	784	699	1033	1543	24.5
25	210	167	317	297	608	496	791	706	1043	1557	25
25.5	212	169	320	300	614	500	798	713	1059	1571	25.5
26	214	171	323	303	620	504	805	720	1064	1585	26
26.5	216	173	326	305	626	508	812	727	1074	1599	26.5
27	219	174	329	308	632	512	818	734	1084	1613	27
27.5	221	176	332	311	638	516	825	741	1094	1627	27.5
28	222	177	335	314	644	520	831	747	1104	1641	28
28.5	224	179	337	317	650	524	838	754	1114	1655	28.5
29	226	180	340	320	656	528	844	760	1124	1669	29
29.5	228	182	343	323	662	532	851	767	1134	1683	29.5
30	230	183	346	325	668	536	857	773	1143	1697	30
30.5	232	185	348	328	674	540	863	780	1153	1711	30.5
31	235	186	351	330	680	544	869	786	1162	1725	31
31.5	236	188	354	333	686	548	876	793	1172	1739	31.5
32	238	189	357	335	692	552	882	799	1181	1753	32
32.5	240	191	360	338	697	556	889	806	1191	1767	32.5
33	242	192	363	340	703	560	895	812	1200	1791	33
33.5	244	194	366	342	709	564	901	818	1209	1795	33.5
34	246	195	369	345	715	568	907	824	1218	1809	34
34.5	248	196	372	247	720	572	913	830	1227	1823	34.5
35	250	197	375	349	726	576	919	836	1235	1837	35
35.5	252	198	377	351	732	580	925	842	1243	1851	35.5
36	254	200	380	354	737	584	931	847	1251	1865	36

Head in Inches	3" Orifice		4" Orifice		5" Orifice		6" Orifice		7" Orifice	Head in Inches
	4 in. Pipe	6 in. Pipe	6 in. Pipe	8 in. Pipe	6 in. Pipe	8 in. Pipe	6 in. Pipe	10 in. Pipe	10 in. Pipe	
36.5	256	201	383	356	743	588	937	852	1259	36.5
37	257	203	385	358	748	592	943	857	1266	37
37.5	259	204	388	360	754	596	949	862	1274	37.5
38	260	205	390	363	759	600	955	867	1281	38
38.5	262	206	393	365	765	604	961	872	1289	38.5
39	263	208	396	367	770	608	967	877	1295	39
39.5	265	209	398	369	776	612	974	882	1304	39.5
40	266	210	401	371	781	616	979	887	1311	40
40.5	267	211	403	373	786	620	985	891	1319	40.5
41	269	212	406	375	790	624	990	896	1326	41
41.5	271	213	408	378	795	628	996	901	1334	41.5
42	272	214	411	380	800	631	1001	906	1341	42
42.5	274	216	413	382	805	635	1007	910	1349	42.5
43	275	217	415	384	810	638	1012	915	1356	43
43.5	277	218	418	386	815	642	1018	920	1364	43.5
44	278	219	420	388	820	645	1023	925	1371	44
44.5	280	220	422	390	824	649	1029	929	1379	44.5
45	281	222	425	392	828	652	1034	934	1387	45
45.5	283	223	427	394	832	656	1040	939	1394	45.5
46	284	224	429	396	837	659	1045	944	1401	46
46.5	285	225	432	399	842	663	1051	948	1409	46.5
47	287	227	434	401	847	666	1056	953	1416	47
47.5	289	228	437	403	851	669	1062	958	1424	47.5
48	290	229	440	405	855	672	1067	963	1431	48
48.5	292	230	442	407	859	676	1073	967	1439	48.5
49	293	231	444	409	863	679	1078	972	1446	49
49.5	294	232	446	411	868	683	1084	977	1454	49.5
50	296	234	448	413	872	686	1089	982	1461	50
50.5	298	235	450	415	876	690	1095	986	1469	50.5
51	300	236	453	417	880	693	1100	991	1476	51
51.5	301	237	455	419	884	697	1105	996	1484	51.5
52	302	238	457	421	888	700	1110	1000	1491	52
52.5	303	239	459	423	892	704	1115	1005	1499	52.5
53	304	240	461	425	896	707	1120	1009	1506	53
53.5	305	241	463	427	900	711	1125	1014	1513	53.5
54	307	243	465	429	904	714	1130	1018	1520	54
54.5	309	244	467	431	908	718	1135	1023	1527	54.5
55	310	246	469	433	912	721	1140	1027	1534	55
55.5	311	247	471	435	915	725	1145	1032	1541	55.5
56	313	248	472	437	919	727	1150	1036	1548	56
56.5	314	249	474	439	923	730	1155	1040	1554	56.5
57	315	250	476	441	927	733	1160	1044	1560	57
57.5	316	251	478	443	930	736	1165	1046	1567	57.5
58	317	252	480	445	934	739	1170	1052	1574	58
58.5	319	253	482	447	938	742	1175	1056	1580	58.5
59	320	254	485	449	942	745	1180	1060	1586	59
59.5	321	256	487	451	945	748	1185	1064	1592	59.5
60	323	257	489	453	948	751	1190	1068	1598	60
60.5	324	258	491	455	951	754	1195	1072		60.5
61	325	259	492	457	955	757	1200	1076		61
61.5	326	261	494	459	958	760	1205	1080		61.5
62	328	262	496	461	961	763	1209	1084		62
62.5	329	263	498	463	964	766	1214	1088		62.5
63	330	264	500	465	968	769	1218	1092		63
63.5	331	265	502	467	971	772	1223	1096		63.5
64	333	266	504	469	974	775	1227	1099		64
64.5	334	267	507	471	977	778	1232	1103		64.5
65	335	268	509	472	981	781	1236	1106		65
65.5	336	269	511	474	984	784	1241	1110		65.5
66	338	271	513	475	988	787	1245	1113		66
67	340	273	517	479	995	793	1254	1120		67
68	343	275	520	483	1002	799	1263	1127		68
69	346	277	523	487	1009	805	1272	1134		69
70	349	280	525	491	1016	811	1280	1140		70

WALLACE & TIERNAN CO., INC.

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Newark 1, New Jersey

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Type MASV Automatic Visible Vacuum Chlorinator

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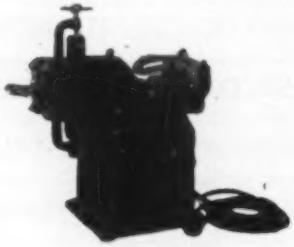

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The Belt Driven unit is a sturdy, dependable unit for use where electric power is not available or where operation is to be synchronized with pumping equipment driven by gasoline engine or other similar motive power.

TYPE MDPA DIRECT FEED AMMONIATOR

A self-contained unit specially adapted to handling ammonia gas, embodying the same sound principles of design and construction exemplified in W&T Chlorinators. Rugged, accurate and dependable.

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For the application of dry chemicals, Wallace & Tiernan offers a complete line of feeding equipment. The Types MO, MOF and MOI Dry Feeders include such advantages as positive agitation, easy calibration and accurate feed over ranges of from 0.5 to 200 pounds per hour, depending upon the chemical used.

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W&T is represented in each of the 35 cities listed above by chlorination specialists to assist in selecting proper equipment for any chlorination problem. Their recommendations involve no obligation.

Current literature on the many phases of chlorination, ammoniation and dry chemical feeding is available on request.

WATER MAIN STERILIZATION

Procedure and Equipment

By HENRY F. MUNROE

Chemical Engineer, Proportioneers, Inc., Providence, R. I.

IT is the intention of this paper to review main sterilization; the need, the procedure, and the available equipment.

Water pipe laying on the ground before installation in a trench is subject to many possibilities of contamination. Also, there is always great possibility of contamination while the line is being made up. One cannot predict when undesirable bacteria are in the soil of the trench, nor can one predict the quality of the water that may find its way into the open end of a pipe.

Recognizing these probabilities, the AWWA has developed an excellent procedure for the disinfection of new and repaired water mains. "*A Procedure for Disinfecting Water Mains 7D.2-1947*"[1,3] is available from the American Water Works Assn., 500 Fifth Ave., New York 18, N. Y. This method has been developed by a committee with years of experience in the disinfection of water mains, and the publication should be considered highly authoritative.

Recommended Procedure

An outline of the recommended procedure of AWWA is:

1. Keep interior of pipes clean. (a) Free of all foreign matter. (b) Swab interior with an effective bactericide. (c) Block open ends to prevent trench water from entering pipe.

2. Joint packing materials (in order of preference). (a) Solid molded or tubular rubber rings. (b) Asbestos rope. (c) Treated paper rope. (d) Braided cotton. (e) Hemp and jute.

3. Before disinfection, main flushing to take place (after pressure test) at velocity of at least 2.5 feet per second.

4. Chlorination. (a) Chlorine or chlorine-water. (b) Chlorinated lime (stabilized-high-test calcium hypochlorite, such as "HTH," "perchloron," "Pitchlor," etc.). (c) Liquid sodium hypochlorite.

5. Point of application to be at one extremity of pipe section with bleed to be at opposite extremity of properly segregated section. Precautions to be taken to prevent water from flowing into potable supply. (a) Injection of chemicals to take place through corporation or cap-cock inserted in the line for that purpose. (b) All high points on section treated to be properly vented for air escape. (c) Rate of application to be such as to give a uniform dose of at least 50 ppm. at end of section of main being treated.

The above outline mentions briefly the important points of main disinfection. Obviously the entire procedure should be carried out under the direction of a competent supervisor.

Most of the above procedure requires no further explanation. However, for review purposes some will be briefly discussed.

Mention has already been made of several of the sources of contamination or recontamination. An outstanding possibility of contamination is the joint packing material used. Some years ago Adams and Kingsbury[2] of the Massachusetts Department of Health conducted extensive experiments on the contamination of water lines by hemp and jute joint packings. The growths of bacteria after short soaking periods in the laboratory were astounding. An involved treatment, not easily followed in routine practice, was required to sterilize this packing. For this reason hemp and jute have been placed at the end of the list of available packing materials. As a matter of fact these two materials have been omitted from the recently revised "Specifications for the Laying of Cast Iron Pipe" of the AWWA.

Preliminary Flushing

The purpose of flushing prior to sterilization is to remove the foreign material that usually finds its way into a new or repaired main. Actual practice has determined that a velocity of more than 3 feet per second is required for scouring; therefore, the flushing procedure should be arranged to give a velocity of 3 to 7 feet per second. The chart presented with this article reveals the volumes of water in gallons per linear foot for the various pipe sizes. From this the bleed rate to obtain the recommended flushing velocity of 3 feet or more per second can be easily calculated.

(*Example*): For a 24 in. main on scale "B" of the chart (5th from left) each foot contains 23.5 gal. For the minimum velocity of 3 ft./sec. the flow must be at least $23.5 \times 3 = 70.5$ gal./sec. or $70.5 \times 60 = 423$ gal./min.

Chlorine Dose

The actual dose of chlorine required depends upon: (a)—the probable degree of contamination; (b)—type of packing used; (c)—the pH of the water. Usually the dose must approximate 100 ppm. in order to secure a residual of not less than 55 ppm. at the end of the line. A main installed in an area where unsanitary conditions prevail will, of course, require a larger dose of chlorine than others. Also, if packing material is used that may harbor and sustain bacteria, a larger dose should be used and the detention periods should be designated "with full pressure applied" to force the solution into the packing if possible.

It is known that the degree and speed of disinfection by chlorine is affected by the pH of the water. Increasing alkalinity of water requires a longer period of contact, or a higher dosage. These factors should be considered when the dosage is being selected. The efficiency of the procedure should, wherever possible, be checked by bacteriological examinations.

Contact Period

The period of contact should be governed by the same factors that determine the dosage. If there is preliminary evidence of contamination a prolonged period, such as 72 hours, should be considered. The average sterilization period is between 24 and 48 hours. Inasmuch as the final removal of the chlorinated water does not involve any other factors than reducing the chlorine content to that commonly used in the finished potable water, the rate of removal of chlorinated water is not important. The line should be bled, however, until the chlorine residual approaches that normally carried in the water system.

Calculations Involved

The uniform application of the sterilizing solution involves the calculation of the gallonage of the pipe line from the size of pipe and length of line to be sterilized. The calculation of the amount of hypochlorite required is determined from the selected chlorine dosage, the available chlorine content of the hypochlorite solution and the

Emergency Set-up of Portable Dual-Drive "Chlor-O-Feeder." A Multi-purpose Feeder Ideal for Water Main Sterilization.

"Rate-Setter" for Attaching to Bleed-off Hydrant.

Eliminates Guesswork in Adjustment of Flow Rate and Chlorine Dosage into Main Being Chlorinated.

bleed rate. In addition, it is necessary to know the duration of the bleed-off period so that the chlorine dosage may be carried to the extremities of the main. The accompanying alignment chart will prove useful in making all of these calculations. The following is an example of how the chart is used.

(*Example*): Let us assume we have 3,000 linear feet of 16 in. main to sterilize with a dose of 100 ppm. available chlorine. We want to know how much 12½ per cent sodium hypochlorite solution will be needed. We also wish to know the rate at which the water must be bled from this section in order to sterilize the line in eight hours. Using the chart—

1—Connect the 3,000 graduation line scale "A" with the line for 16 in. pipe on scale "B"—fifth from left. The intersection of the diagonal line with scale "C" gives the total volume in the section of mains as 31,500 gal.

2—Connect the already determined point on the "C" scale with the desired dose (100 ppm.) on scale "D." The intersection of this line with scale "E" gives the quantity of 12½ per cent sodium hypochlorite required as 25 gal.

3—To determine the bleed rate to do the job in eight hours, from the same 31,500 gal. point on scale "C" extend a line through the eight hour point on scale "G" to scale "F." The point of intersection at 65 gal. per min. is the proper bleed-off rate.

Equipment

Three factors are involved in the selection of the equipment for main sterilization. These are: Feeder capacity, line pressure and operating power.

Capacity

Proportioneers, Inc., has the following equipment available:

1. The standard Heavy Duty Midget Chlor-O-Feeder with a normal design capacity of 5.5 gal. per hr. at an injection pressure of 85 psi. This capacity is obtained by using a 1725 rpm. electric motor, a 50:1 speed reducer and a three-step cone pulley. The above combined with the adjustable stroke length from 0.05 to 0.20 inches gives the design rate of 5.5 gal. per hr. When this unit is particularly adapted for main sterilization, and it is desirable to increase the delivery, a lower ratio speed reducer is employed, or in the case of the gasoline driven unit it is simple to increase the engine speed. By these means the capacity can be increased to approximately 8.5 gal. per hr.
2. The High Pressure Midget Chlor-O-Feeder with a nominal capacity of 5.5 gallons per hour at injection pressures up to 200 psi. As with the Midget Chlor-O-Feeder this capacity is obtained by the use of 1725 RPM electric motor, a 50:1 speed reducer, a three-step cone pulley and a variable stroke length from 0.05 to 0.75 inch. By using a lower ratio speed reducer, or increasing the speed of the gasoline engine of the dual drive unit the capacity can be increased to approximately 8.25 gal. per hr.

The Model 47 Chem-O-Feeders have nominal capacities of multiples of 8.0 gal. per hr. against 100 psi., depending upon number of heads involved. A built-in speed reducer, a 1725 rpm. electric motor and an adjustable stroke length of from 0 to 0.250 inches are employed. The capacity of the single Unit can be increased to approximately 12 gal. per hr. by using a high delivery cam; or, when the gasoline engine-driven unit is furnished, by increasing the engine speed. The Model 47 Chem-O-Feeders are available in Duplex and Triplex styles which deliver 24 to 36 gal. per hr. at pressures up to 125 psi.

Line Pressures

The regular diaphragm feeders are available for pressures up to 85 psi. for the Heavy Duty Midget Chlor-O-Feeder and a maximum of 100 to 125 psi. for the Model 47 Chem-O-Feeders. For higher pressures up to 200 psi. the High Pressure Midget Chlor-O-Feeder is used. The high pressure unit uses a stainless steel piston and a high pressure plastic cylinder.

Operating Power

If the main to be sterlized is in the built-up section it may be possible to use a source of 110/220 volt, 60 or 50 cycle, single-phase current for operation of the feeder motor. Where such current is not readily accessible a small portable gasoline motor can be used.

The Automatic and Proportional Chem-O-Feeder is a unit used for sterilizing mains requiring no outside power whatsoever. Power for operating the feeder is taken from the main itself. The feeding system consists of a disc meter installed in a temporary by-pass line around the segregating gate. This disc meter drives a pilot valve in strict proportion to the flow. The pilot valve transfers water pressure to one side or the other of an actuating diaphragm which in turn motivates a second diaphragm that actually pumps the hypochlorite solution into the by-pass line.

This type of unit has been made up into a compact assembly and is extensively used for emergency work. Holton' used it extensively in Providence after a bacteriological check-up of new mains showed sterilization to be required.

Rate Setter

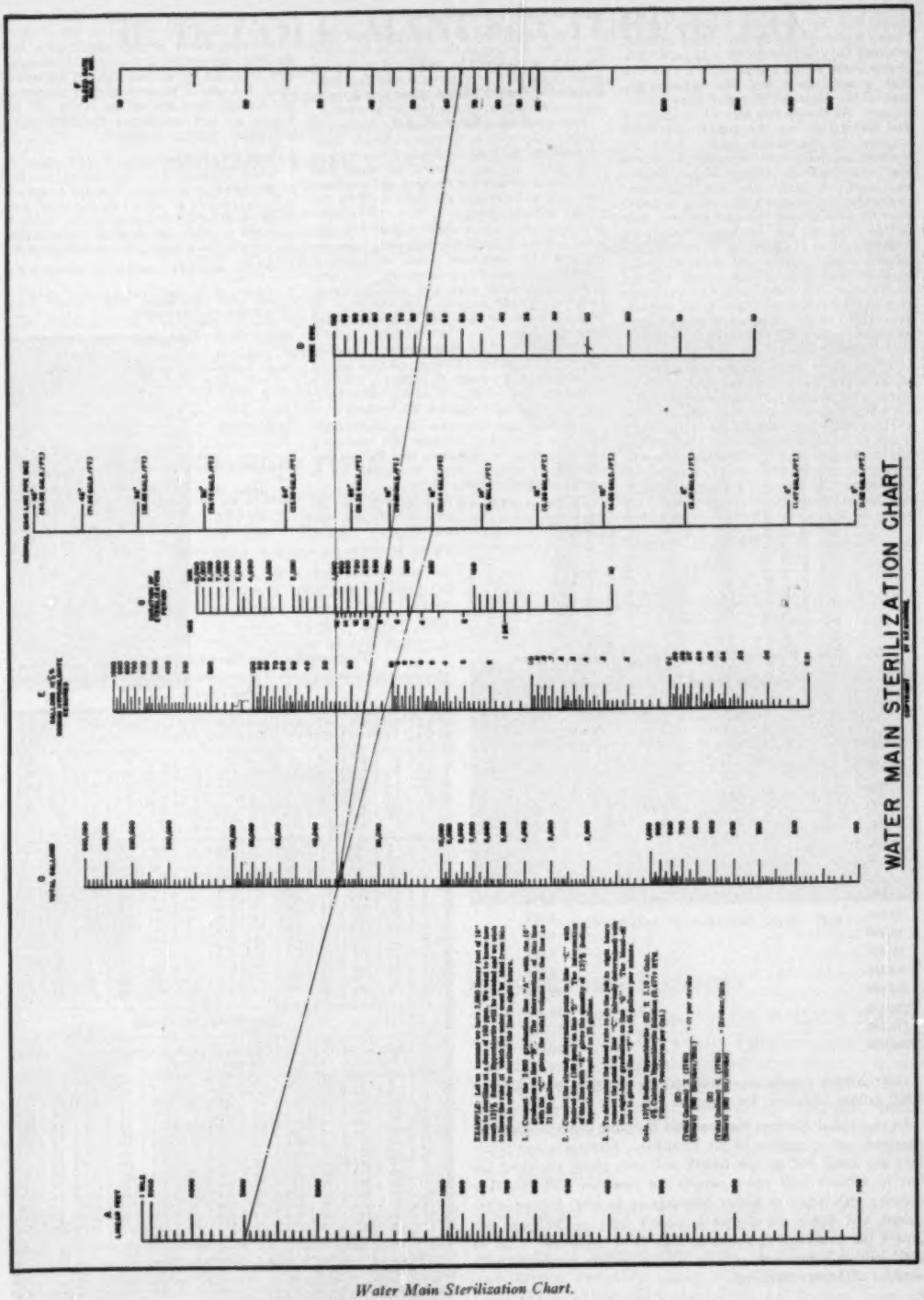
The importance of having a uniform dose throughout the new line was previously mentioned. This is accomplished by injecting the chlorine solution continuously at one extremity while a certain amount is bled off at the other extremity. In order to be certain of a reasonably uniform dosage a definite bleed-off rate must be established. While there are a number of formulae for estimating the discharge from open nozzles, the flow Rate Setter as manufactured by Proportioneers facilitates this procedure, inasmuch as a flow gauge (reading directly in gallons per minute) is attached to the bleed-off hydrant nozzle.

The Rate Setter consists of a National Standard hydrant coupling at one end, a replaceable fixed orifice at the other end and a direct-reading flow gauge for determining the flow from the hydrant in gallons per minute. This converts the complicated problem of estimating or calculating the flow to a simple procedure easily followed by anyone.

Other Methods

The previously outlined procedure constitutes good water works practice, but is by no means the *only* system used. Holton'

Multi-purpose Engine Driven Dual "Chlor-O-Feeder." Showing Carrying Case and Accessories for Main Sterilization or Emergency Chlorination.



Note: Line "B" is between lines "C" and "D". In making the cut of maximum permissible size the letter "B" was sacrificed.—Ed.

Water Main Sterilization Chart.
Developed by the Author to Eliminate Computations in Main Sterilization Problems.

solved a main sterilization problem in Providence, R.I., by sterilizing the new main as it was made up day-by-day. This problem involved the sterilization of a 12-inch high-service main, which was to replace an 8-inch main in accordance with the recommendations of the National Board of Fire Underwriters. As the section was all in ledges, it was decided to use the trench previously occupied by the 8-inch main. Since the replaced sections were immediately placed into service another system of sterilization was used. A pitot tube and manometer were employed on the feeder main to determine the rate of flow through the new main and to calculate the amount of sterilizing solution to dose at 0.25 ppm. Bacteriological samples collected while the main was being replaced showed no positive results and the sterilization was continued for five days after the job was completed. Since no positive results were obtained from the bacteriological tests the treatment was considered effective and the equipment removed.

Heller[5] employed a similar scheme later on, in which small chlorine doses (0.5-2.0 ppm.) were applied for 2 to 3 months while the water was used for other purposes than drinking. For installations where the water is not to be immediately used for drinking this method may be considered. In any event, the effectiveness of all methods of sterilization should be checked by bacteriological examination before permitting the water to be used for human consumption.

Main Sterilization Specifications

Upon completion of installation and testing of any portion or the whole of the main, the new work shall be sterilized under the supervision of a representative of the engineers, the owner, or a company practicing main sterilization, in the following manner:

The pipes shall be thoroughly flushed to remove loose dirt or foreign material. Rate of flushing shall be sufficient to provide a velocity in the line of three to seven feet per second. Water for flushing and sterilization will be furnished the contractor by the owner without charge.

A sterilizing agent consisting of 12½ per cent sodium hypochlorite solution, containing not less than one pound of available chlorine per gallon of concentrate, or a prepared solution of high-test calcium hypochlorite, which contains approximately 70 per cent available chlorine, shall be injected into the main.

The pipe shall be bled at one extremity while injecting the chlorine solution at the other end, long enough to impart a chlorine content of 50 to 100 ppm. of available chlorine by weight throughout the section.

After the line has been completely filled with the sterilizing solution full operating pressure shall be imposed, and the section allowed to remain under treatment for a period of not less than 48 hours.

The main shall then be flushed free of all traces of sterilizing solution, or until the bleed-off water has the same chlorine residual as is normally carried in the system. Upon completion of the sterilization and flushing, the sterilized line shall be sampled and analyzed by an experienced bacteriologist and placed in service upon receipt of his written approval of the water. If the results are not satisfactory the sterilization procedure must be repeated.

Consult the Literature

When developing a department practice or procedure, it is always of value to review the experiences of others in the same line. References to the literature given below is included to assist in such an investigation.

1.—Calvert, Cecil—Main Disinfection JAWWA 40.2 125 (1948)
2.—A Procedure for Disinfecting Water Mains 7D.2 (1947)
3.—Adams, G. O. and Kingsbury, F. H.—Experiences with Chlorinating New Water Mains JNEWWA 51:2:60 (1937)
4.—Holton, Phillip V., Jr.—Chlorinating New Mains—Water Works Engineering (February 14, 1940)
5.—Heller, A. N.—Proposed Plant for Water Main Sterilization JAWWA 35:2:168 (1943)
6.—Smith, Fred E.—Chlorination of a Cambridge Main JNEWWA 51:2.57 (1937)
7.—Weir, W. Victor—Emergency Repairs of Distribution Systems JAWWA 34:8.1205 (1942)
8.—Armbrust, H. N.—Emergency Equipment for Sterilization and Its Application—Jour. Main Water Utilities Association (1941)
9.—Moore, Charles R.—Chlorination; Routine and Emergency Water Works and Sewerage (March, 1943)
10.—Shaw, Percy—Cleaning, Sterilizing and Incorporating the Amoskeag Mills Water System into the Manchester, N.H. City System JNEWWA Vol. LVI.#2:212 (June, 1942)

Fire Flows Required for Towns of Various Sizes, by National Board of Underwriters

Population	Required Fire Flow, Gallons per Minute for Average City
1,000	1,000
2,000	1,500
4,000	2,000
6,000	2,500
10,000	3,000
13,000	3,500
17,000	4,000
22,000	4,500
28,000	5,000
40,000	6,000
50,000	7,000
80,000	8,000
100,000	9,000
125,000	10,000
150,000	11,000
200,000	12,000

Over 200,000 population, 12,000 gallons a minute, with 2,000 to 8,000 gallons additional for a second fire.

In residential districts the required fire flow depends upon the character and congestion of the buildings. Sections where buildings are small and of low height and with about one-third the lots in a block built upon, require not less than 500 gallons a minute; with larger or higher buildings up to 1,000 gallons is required, and where the district is closely built, or buildings approach the dimension of hotels or high value residences, 1,500 to 3,000 gallons is required, with up to 6,000 gallons in densely built sections of 3-story buildings.

Commercial Pipe Sizes for Fire Streams*

Number of 1 1/8-Inch Hose Nozzles	Ordinary Fire Streams											
	40 Pounds Pressure		50 Pounds Pressure		60 Pounds Pressure		70 Pounds Pressure		80 Pounds Pressure		90 Pounds Pressure	
	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.
1	4	20	6	23	6	25	6	27	6	29	6	30
2	6	40	8	45	8	50	8	53	8	57	8	61
3	8	61	8	68	10	74	10	80	10	86	10	91
4	10	81	10	90	10	99	10	107	12	114	12	121
5	10	101	12	113	12	124	12	134	12	143	12	152
6	12	121	12	135	12	149	12	160	14	172	14	182
7	12	141	14	158	14	174	14	187	14	200	16	212
8	12	162	14	181	14	199	16	214	16	229	16	242
9	14	182	14	203	16	223	16	241	16	257	18	273
10	14	202	16	226	16	248	16	267	18	286	18	303
11	16	222	16	248	18	273	18	294	18	314	18	333
12	16	243	18	271	18	298	18	321	20	343	20	364
13	16	263	18	293	18	323	20	348	20	372	20	394
14	18	283	18	316	20	348	20	374	20	400	20	424
15	18	303	20	339	20	372	20	401	20	429	24	455
	High-Pressure Fire Streams											
	100 Pounds Pressure		110 Pounds Pressure		120 Pounds Pressure		130 Pounds Pressure		140 Pounds Pressure		150 Pounds Pressure	
1	6	32	6	33	6	35	6	36	6	38	6	39
2	8	64	8	67	10	70	10	73	10	75	10	78
3	10	96	10	100	10	105	10	109	12	113	12	117
4	12	128	12	134	12	140	12	145	12	151	14	156
5	14	160	14	167	14	174	14	181	14	188	14	195
6	14	191	14	200	14	209	14	218	16	226	16	234
7	16	223	16	234	16	244	16	254	16	264	18	273
8	16	255	16	267	16	279	18	290	18	301	18	313
9	18	287	18	301	18	314	18	326	18	339	20	352
10	18	319	18	334	20	349	20	363	20	377	20	391
11	20	351	20	367	20	384	20	399	20	414	20	430
12	20	383	20	401	20	419	20	435	24	452	24	469
13	20	415	20	434	24	454	24	472	24	490	24	508
14	24	447	24	467	24	488	24	508	24	528	24	547
15	24	479	24	501	24	523	24	544	24	565	24	586

To convert cubic feet to gallons, multiply by 7.4805.

In calculating above table, the following assumptions were made: Nozzles, 1 1/8-inch smooth bore, playing simultaneously, and attached to 200 feet of best quality rubber-lined hose; pressures measured at hose connections; velocity of water in pipe approximately 3 feet per second.

*Reproduced by courtesy of N. S. Hill, Jr.

R. D. COLE MANUFACTURING CO.

Est. 1854

Tanks, Towers, and Steel Plate Work

NEWNAN, GA.

5,000 TO 2,000,000-GALLON WATER TANKS

All shapes and sizes—The R. D. COLE MANUFACTURING CO. has developed a complete line of elevated steel tanks for water supply, both for domestic service and sprinkler requirements, ranging in capacity from 5,000 to 2,000,000 gallons.

The designs include the standard Hemispherical Self-supporting Bottom, the "Cole Ovaloid," Standpipe and many individual styles involving architectural treatment to satisfy local conditions, or to provide special shapes for advertising purposes.

STORAGE TANKS

Pressure tanks for storage of gas from digesters at sewage disposal plants so that excess output at peak loads can be used during off-peak periods. Chemical storage tanks, hot water storage tanks, tanks for bulk storage of oils and gas.

Designs Available for Any Service

1,000,000-Gallon "Cole-Shallow Depth" Tank

CONSTRUCTION FACILITIES

Fabricated Steel Plate—The R. D. COLE MANUFACTURING CO. has a fully equipped plant for the fabrication of riveted or welded steel plate. In addition to the construction of its regular line of horizontal return tubular boilers, oil storage tanks, tubular heaters, etc., the company is prepared to construct special tanks and apparatus of any specified metal plate.

Alloys and Lining for Processing Apparatus—The facilities and experience of the company enable it to fabricate special apparatus of all kinds for the processing industry using alloy steel plates, stainless steel, nickel-clad steel, etc., or linings such as lead, tin, nickel or Monel.

Capacities and Sizes OF STANDARD ELEVATED *by* PITTSBURGH · DES MOINES

In these compact but complete tables, data are furnished on the various types of elevated steel tanks, and on steel reservoirs. For full information as to the application of these tanks, for designs, for specifications, or for estimates, write—without obligation—to our nearest office.

Table I — Small Capacity Hemispherical Bottom Tanks

Capacity in U. S. Gallons	TANK DIMENSIONS				Number of Columns
	D	V	B	C*	
5,000	9' 0"	11' 0⅛"	1' 2½"	9' 9⅛"†	4
10,000	13' 0"	11' 7¾"	6' 0"	9' 7¾"	4
15,000	13' 0"	16' 10¾"	6' 0"	10' 10¾"	4
20,000	13' 0"	21' 8"	6' 0"	15' 8"	4

*This column lists height of the tank cylinder up to the high water line. The cylinder actually extends 3 inches above the high water line.

†The bottom of this 5,000 gallon tank is a sector of a 9 ft. radius sphere.

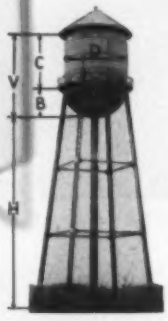


Table II — Standard Hemispherical Bottom Tanks

Capacity in U. S. Gallons	TANK DIMENSIONS				Number of Columns
	D	V	B	C*	
25,000	13' 0"	19' 10½"	5' 4"	14' 6½"	4
30,000	13' 0"	23' 8½"	5' 4"	18' 4½"	4
40,000	17' 0"	24' 11¼"	6' 8"	18' 3¼"	4
50,000	19' 0"	25' 6"	8' 0"	17' 6"	4
60,000	19' 0"	30' 3½"	8' 0"	22' 3½"	4
75,000	21' 0"	30' 6¾"	8' 0"	22' 6¾"	4
100,000	24' 0"	30' 11½"	8' 6"	22' 5½"	4
150,000	28' 0"	34' 5½"	10' 5"	24' 0½"	4
200,000	32' 0"	35' 11½"	12' 9"	23' 2½"	6

* This column lists height of the tank cylinder up to the high water line. The cylinder actually extends 3 inches above the high water line.

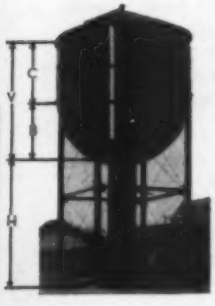
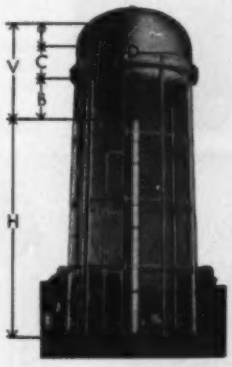


Table III — Railroad Type Hemispherical Bottom Tanks

Capacity in U. S. Gallons	TANK DIMENSIONS				Number of Columns
	D	V	B	C*	
25,000	15' 0"	19' 7½"	5' 4"	14' 3½"	4
30,000	17' 0"	18' 8½"	6' 5"	12' 3½"	4
40,000	19' 0"	20' 2½"	7' 5"	12' 9¾"	4
50,000	21' 0"	20' 9½"	8' 0"	12' 9½"	4
60,000	24' 0"	19' 11½"	10' 2"	9' 9½"	4
75,000	24' 0"	23' 6½"	8' 9"	14' 9½"	4
100,000	28' 0"	23' 3½"	10' 2"	13' 1½"	4
150,000	28' 0"	34' 5½"	10' 5"	24' 0½"	4
200,000	36' 0"	28' 11"	14' 1"	14' 10"	6

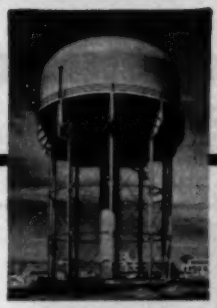
* This column lists height of tank cylinder up to the high water line. The cylinder actually extends 3 inches above the high water line.

Table IV—Double Ellipsoidal Welded Elevated Tanks



Capacity U. S. Gallons	TANK DIMENSIONS				
	D	V	B	C	T
25,000	18' 0"	14' 4⅜"	4' 9"	6' 0⅛"	3' 7⅜"
30,000	18' 0"	17' 0"	4' 9"	8' 7⅛"	3' 7⅛"
40,000	20' 0"	18' 6⅜"	5' 2⅝"	9' 4⅛"	4' 0"
50,000	22' 0"	19' 2½"	5' 11"	8' 10⅛"	4' 4⅛"
60,000	24' 0"	19' 7⅛"	6' 4⅜"	8' 5⅛"	4' 9⅛"
75,000	26' 0"	21' 2⅜"	6' 10⅛"	9' 1⅛"	5' 2⅝"
100,000	28' 0"	23' 8⅜"	8' 7"	9' 6⅛"	5' 7⅛"
150,000	32' 0"	27' 4"	9' 4⅜"	11' 7"	6' 4⅜"
200,000	36' 0"	29' 4⅛"	10' 6⅜"	11' 7⅜"	7' 2⅛"
250,000	38' 0"	33' 0"	11' 3⅝"	14' 3⅛"	7' 4⅜"
300,000	44' 0"	30' 9"	13' 0⅛"	7' 11⅜"	9' 8⅛"
400,000	48' 0"	34' 3⅜"	14' 7"	11' 0"	8' 8⅛"
500,000	50' 0"	39' 0⅝"	15' 6⅛"	15' 5⅛"	8' 0⅛"
600,000	50' 0"	45' 10⅜"	15' 6⅛"	22' 3⅛"	8' 0⅛"
750,000	60' 0"	41' 7⅜"	18' 0"	11' 10⅜"	11' 9"
1,000,000	68' 0"	47' 1⅜"	20' 1⅛"	16' 5⅜"	10' 5⅛"
1,250,000	70' 0"	51' 2⅛"	23' 9"	19' 5⅛"	8' 9"
1,500,000	70' 0"	59' 10⅛"	23' 9"	28' 1⅛"	8' 9"

STEEL TANKS



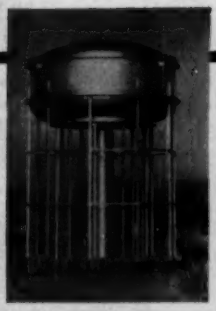


Table V—Low Head Range Tanks having Shallow Supported or Combination Suspended and Supported Bottoms

(a) These tanks are available in the following types:

Toroidal Bottom Tanks with Dome Roofs.
Toroidal Bottom Tanks with Ellipsoidal Roofs.
Toro-segmental Bottom Tanks with Ellipsoidal Roofs.
Obloidal Tanks.
Radial Cone Tanks.

(b) One or more of these types are available in the following sizes:

500,000 U. S. Gallons.
750,000 U. S. Gallons.
1,000,000 U. S. Gallons.
1,250,000 U. S. Gallons.
1,500,000 U. S. Gallons.
2,000,000 U. S. Gallons.
2,500,000 U. S. Gallons.

(c) These tanks are built in standard head ranges of 25' 0", 30' 0" or 35' 0".

Table VI—Supporting Towers for Elevated Tanks

(a) Standard Heights:

The height of elevated tank structures is measured from the underside of the bases of the steel columns to the lower capacity level. The following are considered standard heights:

Up to 50 ft. by even 2-ft. intervals.
From 50 ft. to 100 ft. by even 5-ft. intervals.
Over 100 ft. by even 10-ft. intervals.

(b) Tower Types:

Structural, latticed column.
Structural, H column.
Tubular column.

Generally speaking, columns in the tower of an elevated tank are inclined so that the column spread at the base is greater than at the top. This reduces the overturning effect of wind, which makes for economy in the tower itself and in the foundations. For low towers, however, where the overturning force of wind is not so great, the columns may be vertical; and for large capacity, large diameter tanks, particularly where tubular columns are selected, the tower columns may be vertical.

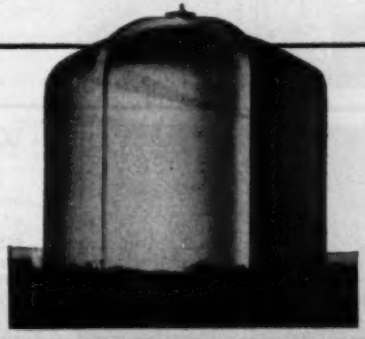


Table VII—Steel Reservoirs

Capacity in U. S. Gallons	Diameter	Height
50,000	20'	21' 6"
60,000	22'	21' 6"
75,000	24'	22' 6"
100,000	26'	25' 6"
150,000	30'	28' 9"
200,000	34'	29' 9"
250,000	38'	29' 9"
300,000	42'	29' 3"
400,000	46'	32' 6"
500,000	50'	34' 6"
750,000	60'	35' 9"
1,000,000	70'	35' 0"
1,500,000	80'	40' 3"
2,000,000	95'	38' 3"
2,500,000	110'	39' 6"
3,000,000	120'	39' 9"
4,000,000	130'	40' 9"

PITTSBURGH • DES MOINES STEEL CO.

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SEATTLE 926 Lane Street
SANTA CLARA, CAL. 625 Alviso Road

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Atlanta 3.....2181 Healey Building
Birmingham 1.....1586 North Fiftieth Street
Boston 10.....1040—201 Devonshire Street
Chicago 4.....2199 McCormick Building
Cleveland 15.....2262 Guildhall Building
Detroit 26.....1551 Lafayette Building
Houston 2.....2115 National Standard Building
Los Angeles 17.....1656 General Petroleum Building
New York 6.....3290—165 Broadway Building
Philadelphia 3.....1649—1700 Walnut Street Building
Salt Lake City 4.....550 West 17th South Street
San Francisco 4.....1583—200 Bush Street
Seattle 1.....1350 Henry Building
Tulsa 3.....1646 Hunt Building
Washington 6, D.C.....1109 Cafritz Building

Plants in BIRMINGHAM, CHICAGO, SALT LAKE CITY and GREENVILLE, PENNSYLVANIA

ELLIPSOIDAL-BOTTOM TANKS

These welded steel water tanks have a relatively large diameter and shallow depth to reduce pressure variations. The riser is welded directly to the tank eliminating an expansion joint. Standard capacities are shown below.

Gallons Capacity	Tank Dimensions	
	Diameter	Range
50,000	22'0"	19'0"
60,000	24'0"	19'0"
75,000	26'0"	21'0"
100,000	28'0"	24'0"
125,000	30'0"	25'5"
150,000	32'0"	27'6"
200,000	36'0"	29'6"
250,000	40'0"	29'0"
300,000	43'0"	30'0"
400,000	46'0"	35'0"
500,000	50'0"	37'6"

RADIAL-CONE BOTTOM TANKS

The radial-cone bottom design makes it possible to build these large capacity tanks with low range-in-head. The result is substantially lower pumping costs. Exterior construction details may be varied to secure the desired architectural effect.

Gallons Capacity	Tank Dimensions	
	Diameter	Range
500,000	60'4"	25'
750,000	74'3"	25'
750,000	67'6"	30'
1,000,000	86'0"	25'
1,000,000	78'0"	30'
1,000,000	71'6"	35'
1,500,000	104'0"	25'
1,500,000	96'0"	30'
1,500,000	88'0"	35'
2,000,000	112'0"	30'
2,000,000	102'0"	35'
2,500,000	114'0"	35'
3,000,000	117'0"	40'

WATERSPHERES

Here are modern elevated water tanks of welded steel construction that are ideal for installation in residential or other high value areas. All piping connections are located inside the supporting column. Easy access to the top of the Watersphere makes it possible to paint the entire structure more economically. These tanks are built in accordance with AWWA specifications. A listing of capacities is shown at the right.

CAPACITY IN GALLONS	DIAMETER OF SPHERE
25,000	19'4"
30,000	20'4"
40,000	22'4"
50,000	24'0"
60,000	25'6"
75,000	27'4"
100,000	30'0"
150,000	34'0"
200,000	37'6"
250,000	40'6"

Write our nearest office for estimating figures.

GUIDE FOR WATER TANK MAINTENANCE INSPECTION

J. O. JACKSON

Vice Pres. in Charge of Engineering & Research

Pittsburgh-Des Moines Co., Pittsburgh, Pa.

THE service life of elevated steel water tanks, standpipes, and reservoirs depends upon regular inspection, maintenance, and repair. Steel is an ideal tank construction material. It has dependable strength, is easy to make leakproof, and is inexpensive to maintain. Properly maintained steel tanks need very little repair. For this reason the tendency is to omit important periodic inspections and thereby neglect the small amount of maintenance which will avoid costly replacement. If the tank is neglected, corrosion, often concentrated by electrolysis, progresses so rapidly that many parts may be damaged beyond repair in a very short time.

Corrosion control is unquestionably the most important kind of maintenance. Corrosion cannot be entirely prevented but it can be minimized with an adequate paint film or other protective means. This article outlines the best method of maintaining steel water tanks, with emphasis on the important parts which should be inspected regularly and repaired as necessary. Paint maintenance is so important that it is covered in a separate article entitled "Repainting Steel Water Tanks." (For location of this article refer to Index this issue.)

The prime requisite of a successful maintenance program is a thorough annual inspection made by a person competent to recognize situations which are or may become serious. A detailed report should then be made to the person responsible for the maintenance of the tank so that proper measures can be taken to make the necessary repairs.

If the owner of the tank has in his organization a department or a man charged with property maintenance, this man is the logical one to make the inspection and report. If no such person is employed, an engineer is probably the best qualified; otherwise the services of an outside inspection agency should be secured. Manufacturers of steel water tanks usually have available, at a reasonable price, an inspection service. They can be depended upon by the owner to do a conscientious job.

The following procedure is suggested as guidance for the inspector, once he is obtained.

General

1. "SAFETY FIRST." Be careful while inspecting the structure. Be sure ladders are safe. Do not lean on railings. Do not climb on roof and do not attach lines to parts of the tank until you have found that they are in good condition. Beware of spider rods. The structure may not have been properly cared for and parts may not be safe. *BE CAREFUL.*

2. Have the tank emptied and have the inside of the shell washed down with a fire hose, and the dirt and mud cleaned out from the tank bottom so that it may be properly inspected.

3. The deterioration which you might find will usually have been caused by rust which has resulted from the neglect of the owner to keep the tank properly painted. Below are various specified items which should be carefully examined. In each case make a careful inspection and advise:

a. Condition of paint; give approximate per cent of rusted areas.
b. How much the metal has rusted; give your ideas of length of life remaining in tank.
c. The extent and depth of pitting; give complete answers. Do not evade questions with such answers as "fair," "needs repairs," etc. Remember that this inspection is important and the owner deserves complete information.
d. In cases where pitting has occurred, advise whether this pitting is localized in spots that can be repaired, or whether the pitting is general, requiring new sheets or structural members. If new material is required, state amount and location.

4. Give no information to anyone other than the persons who employ you for this work.

The following is a suggested inspection report form which has been developed over many years use, and which has been found to give good results.

Inspection Report

1. Are anchor bolts rusted so as to materially reduce their strength? If so, caliper and advise smallest section. If possible, examine carefully where bolts enter concrete. .....

2. Are anchor bolt nuts tight? .....

3. Are column shoes in good condition? Are they clean and painted or has dirt accumulated? If seriously rusted, state where and depth of rust. .....

4. Are anchor bolt connections on standpipes in good condition or has their strength been materially reduced by rust? .....

5. Are tower posts in line? .....

6. Is there any indication of settlement in the foundations? .....

7. Are tower rods in good adjustment? .....

8. Are tower rods in good condition? If they are badly rusted so as to reduce strength, measure the smallest part and report. Be sure to state in what rods this occurs. Examine particularly condition of rods around pins. .....

9. Are there two cotter pins well spread in each end of all long pins and one cotter pin well spread in each upset pin? If rod pins with nuts are used, advise if nuts are on with full thread and the end of thread well battered. This is important. If cotters come out or nuts drop off, pins may come out with the result that tank bracing will be loosened and the structure may collapse. Examine each pin. .....

10. Is riser pipe straight? .....

11. Are riser pipe stay rods in good condition? .....

12. Is the frost casing in good condition? .....

13. Is the frost casing supported by substantial foundation? .....

14. Are there any indications of leaks in riser pipe or in expansion joint? .....

15. Are there any indications of leaks in tanks? .....

16. Is the ladder safe? .....

17. Is the balcony safe? .....

18. Is balcony floor in good condition? State the amount of rust and how much dirt has accumulated thereon. .....

19. Report any bolts or rivets which are not in place in the splice connections of the tower, struts and balcony. .....

20. State condition of paint and metal of tower. Look particularly inside of columns and struts, under lacing bars, at post connections, at strut connections, and at all more or less difficult and concealed places. .....

21. State condition of paint and metal of outside of tank bottom. Look particularly underneath balcony and post connections. .....

22. State condition of paint and metal outside of tank shell. .....

23. State condition of paint and metal on outside of roof and under eaves of roof. .....

24. Is final connection solid or is the roof badly rusted at peak and is there danger of the finial blowing or falling off? .....

25. Was tank emptied for inspection? If not completely emptied, state how far down. .....

26. State condition of paint and metal inside of roof. .....

27. State condition of spider and spider rods. .....

28. State condition of inside ladder. .....

29. State condition of paint and metal inside of tank shell. Go over the entire shell. Determine exact condition of metal underneath and the extent of rust and pitting. .....

30. State condition of paint and metal inside bottom. .....

31. State condition of paint and metal inside large riser, particularly at the bottom. .....

32. State condition of rivets at lap joints and at post connections. .....

33. State condition of metal between rivets at the laps and at the post connections. .....

Ed Note: For an article on "Repainting Steel Water Tanks" by Mr. Jackson, see the magazine section this issue. Intended as a companion article, it arrived too late for use in this section.

34. Examine any valves and advise if leaking. This refers particularly to blow-off valve, if furnished.....

35. Is bottom covered with mud or scale; if so, to what depth?.....

36. Does outlet pipe stick up above accumulations of scale or are there indications that some of this dirt and scale has entered the outlet pipe?.....

37. Structure was painted last about .....
Previous to that it was painted about.....
Previous to that it was painted about.....

38. General statements as to condition of structure.....

39. Repairs made by inspector.....

40. Repairs recommended.....

41. Inspection report should be sent to .....

Making the Repairs

Having received the report from the inspector, the person responsible for the proper maintenance of the tank will undoubtedly want to discuss in detail the findings of the inspector. After such discussion, plans for making the repairs should be made. If the repairs consist only of things the owner can take care of himself, or with his own forces, orders should be issued to have the work done and the report should be noted to indicate that each item in the inspection was properly taken care of.

If the repairs are extensive the owner may wish to advertise for bids and have the work done by some competent organization. The owner must assume the responsibility for seeing that the organization engaged to do the work will do it conscientiously and at a reasonable price. It is recommended that the owner have this inspection and repairing done in accordance with the Tentative Recommended Practice for Inspecting, Repairing and Repainting Elevated Steel Water Tanks, Standpipes and Reservoirs of the American Water Works Association Specification No. 7H, 2-T, latest revision.

Caution

If the tank is used for sprinkler or fire protection service, your insurance company and the local fire department should be notified when the tank is to be taken out of service and how long it will be out.

If the tank is used for municipal water supply, the fire department should be notified of the time the tank will be out of service, and unless other sources are available special provision should be made for emergency water supply in case of fire.

PAINTING DAMP WATER PIPES

In reply to a question regarding the painting of plant piping which is wet from condensed moisture and cannot be taken out of service long enough to dry, The New Jersey Zinc Company prints the following in its periodical, "Paint Progress." The engineer, by the way, stated that wiping the pipes with dry rags before painting had not been satisfactory.

Says New Jersey Zinc:

"We have seen good results obtained by using a turpentine wash to replace the moisture on the pipes and have, as a result, adopted the following method in our own plants:

"The surface is prepared for painting by removing the loose paint and scale by wire brushing and scraping. The dirt and excess moisture are then wiped off the surface and a liberal coating of turpentine is applied.

"The turpentine has a two-fold effect: first to replace the water remaining on the surafce by virtue of its preferential wetting property, and second, to 'lift' any loose rust scale remaining on the surface after the mechanical cleaning. A primer coat of standard Zinc Dust-Zinc Oxide paint is then applied directly on the turpentine wet surface, thus providing the necessary rust inhibitive coating. In actual practice, a considerable interval may be allowed between the application of the turpentine and the primer, since the turpentine prevents further condensation of water on the steel.

"Brush application of the primer is preferred to spray application, since it insures the intimate contact of the Zinc Dust with the surface. An 80:20 Zinc Dust-Zinc Oxide formula with a linseed oil vehicle has been used, but a synthetic vehicle, such as phenolic, may be preferable, first, because of the more rapid drying of the synthetic resin formulation, and second, because of the improved water resistance of the film.

"The usual drying interval is allowed, after which the finish coat paint is applied. Just before the application of the second coat, the moist surface is again wiped with turpentine, but care must be taken to avoid an excess of the turpentine, since it might soften the surface of the primer.

"Either an 80:20 Zinc Dust-Zinc Oxide paint or other suitable metal paint may be used as the finish coat. Colored Zinc Dust paints are available for finishing coats where a distinctive color scheme is desired.

"It has been found that kerosene may be substituted for turpentine to replace moisture on the pipes, but its action is much slower and its assimilation into the paint less positive."

MAINTENANCE OF WATER WELLS

By N. E. GUNDERSON
President, Layne-Northern Company, Inc., Mishawaka, Ind.

IN THE matter of water well maintenance, the principal trouble encountered is shortage of water. When such a shortage occurs, it is necessary to have all of the facts regarding a particular well in order to determine the cause. There are three principal causes for shortage of water supply. First, there is always the question as to whether the ground water level has lowered and decreased the available supply of water. Second, the condition of the well itself as it affects the capacity. Third, the condition of the pumping unit.

In order to make a proper diagnosis of the condition of a well, it is necessary to compare present operation with the operation at some time in the past, preferably original operating conditions. When a new well is constructed, the owner is entitled to three definite reports. First, a well log should be kept as the well is drilled, listing each different underground formation as it is found, noting particularly where water is encountered, a point very important in rock holes. Second, a drawing of the well should be made, giving all dimensions and length of casing, screen, and shoes. Third, a complete test should be run on the well. The latter involves a determination of the static or standing water level when the well is not pumping, then the pumping level and the gallons per minute yield for a pumping period of four to eight hours, or until the water level is stabilized.

The owner is also entitled to the same complete information on the pump installation. This should include the characteristic curve on the pump, the length and size of discharge column, the length and number of stages of pump bowl, the length and diameter of suction pipe, and the length of the air line below the base plate.

Well Tests

As soon as well trouble is experienced, a test should be run to determine current operating conditions. It is also good practice to run a test of this kind periodically thereafter, since it may be possible to predict trouble from the data at hand before it occurs. The instruments needed to run a proper test are a water meter or simple orifice plate; an air line in the well, with a suitable altitude gauge at the top; and a pressure gauge on the discharge of the pump. For the test the following should be determined: the static water level and water level after starting the pump, water level after pumping several hours, gallons per minute delivery, air line reading, and pounds pressure at the pump discharge.

The static level subtracted from the pumping level gives the drawdown or distance in feet the water level recedes when the well is delivering. Dividing the gallons per minute by the draw-down gives the yield of the well in "gallons per minute per foot of drawdown." This is the specific capacity of the well and is a very important figure.

For example, if a new well had a static water level 40 feet below the surface, delivered 200 gallons per minutes, and had a pumping water level 50 feet below the surface, the specific capacity was 20 gallons per minute per foot of drawdown. If the same well at a later date showed 200 gallons per minute at a 60-foot pumping level, the specific capacity is 10 gallons per foot, or only one-half of the original yield.

Static Level

If the present static level is compared with the static level measured several years ago, or when the well was new, it can readily be determined whether the ground water level has lowered. Since there is often a minor seasonal fluctuation of ground water level, it is preferable to take periodic sets of readings throughout the year; or, as next best, to compare readings taken at the same time of each year.

If it is determined that the static water level in the ground has dropped to a considerable extent, the only practicable remedy is, of course, to locate a deeper formation, or to look for a new well field if the lowering has become serious. In an area where only reasonable demands are made upon the water bearing formations, however, this question is not likely to become serious, because the available rainfall in the area is ample to recharge the underground formation, except in cases of extreme demand.

Causes of Well Troubles

If the tests indicate that the specific yield of the well has been reduced to a considerable extent by causes other than a lowering of ground water level, the condition of the well itself should be examined to determine the true cause of the trouble. Mechanical trouble may be caused by loose material collected in the bottom. The material may come in through a hole in the casing or screen, or under the shoe of the casing. Old wells may entirely collapse due to corrosion of the casing. If it is determined that there is no mechanical trouble in the well, it is entirely possible that chemical trouble may have developed. This chemical trouble is the deposition of salt of lime and/or iron around the screen and in the water bearing formations back some considerable distance from the screen. Originally, when rain water soaks through the ground, it carries sufficient carbon dioxide to dissolve lime and iron from the soil and from the limestone formation. Thus water often becomes saturated with carbonate of lime and iron compounds which tend to precipitate from the water on reduction in pressure, which permits the carbon dioxide gas to escape. The drop in pressure which brings on the deposition is caused by the drawdown of the well which represents the drop in pressure of the ground water required to bring the water into the well. Stalactites and stalagmites in limestone caverns are of the same material as forms in a well. The deposit which forms on all types of screen material has the appearance of grey to red putty when it is brought out of the well and examined, and usually hardens upon exposure to air. The tendency of a well water to produce this deposit seems to be based more on its stability than on its hardness. In some cases, quite hard water forms no deposit; while, in others, a water of low hardness will produce a deposit very rapidly.

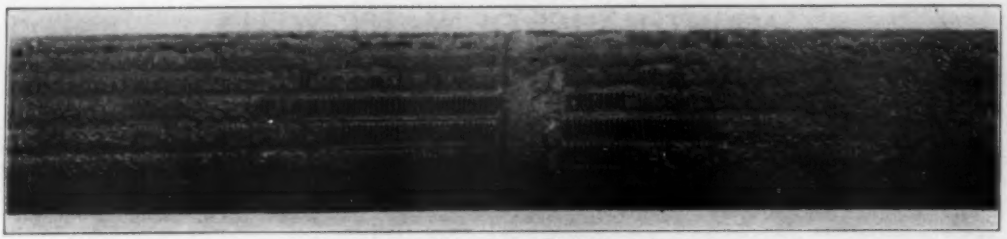
Pump Troubles

In order to determine possible pump trouble, it is necessary to know the total pumping head. Therefore, obtain the reading of the pump pressure gauge and convert this reading to feet. From the air line reading determine the pumping level or lift below ground. Adding the pressure in feet to the lift below ground in feet will give the total lift. Compare the gallons per minute produced at this total lift with the original pump curve and the condition of the pump can be readily determined.

If the pump is not producing the proper gallons or lift, the trouble may be caused by worn bearings or by this same chemical deposit building up in the impellers, thus choking off the flow.

If it is found that the decrease in capacity is due to worn parts, the first step is, of course, to consult the pump manufacturer. Due to the scarcity of repair materials, it is extremely advisable to pull the pump on a regular schedule, possibly every two years, and check all bearings for wear. On an oil lubricated pump it is entirely practicable to reverse the shafting in order to expose a new bearing surface, and it is also possible, by adding a short section of shafting at the bottom, to move the shafting up to a new bearing surface. Every time the pump is pulled it is good practice to thoroughly clean and paint the discharge column in an effort to reduce corrosion on the surface. Only a good metal

Thousand-Gallon Acid Truck
Delivering Acid Directly to Job from Bulk Station



Encrusted 18-In. Screen After Eight Years' Service
(A Job for Acid Treatment)

paint should be used which will adhere firmly to the surface.

When setting the pump in the well, as a precaution place a small rubber band around the pump bowl at top and bottom, particularly if the pump is finally set in the screen or in a casing only slightly larger than the pump. This rubber band can be cut from a section of inner tube. Any pump when running has a slight vibration, which in several cases is known to have actually cut through the screen or casing.

If the water is corrosive and the pump is pitting badly, it may be possible to reduce pitting by placing a small cylinder of zinc plate inside the horizontal discharge pipe next to the pump head, and another zinc cylinder inside the suction pipe just below the pump bowl. These should be riveted tightly inside the pipe, using iron rivets.

Mechanical Methods of Well Cleaning

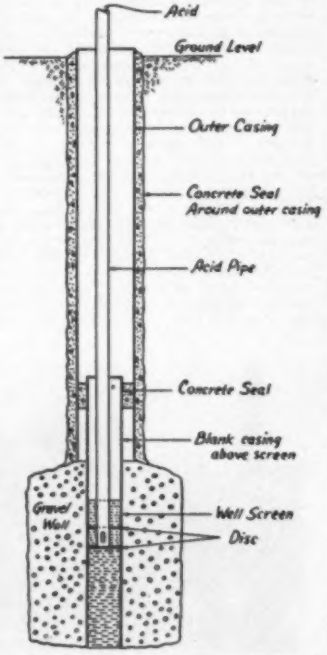
In the operation of rock wells it is quite possible for loose material to accumulate in the bottom. Such loose material may come from a hole in the casing or under the shoe. Each time the pump is removed the well depth should be carefully measured and compared with the original well depth. As explained previously, a deposit may build up in the crevices or on the wall of the rock hole. If a set of drilling tools is run in the well it is likely to brush off most of the deposit on the walls of the well. Any deposit back in the crevices can be removed only by shooting the well or by the use of acid.

If the original log indicates the depth at which the water was encountered, it is good practice to place light shots of dynamite, spaced 10 to 25 feet apart, at these old water levels with each shot ranging from 10 to 50 pounds. The principal danger in shooting is in placing the shots too close to the bottom of the casing. A peculiar fact about shooting wells is that rupture of the casing is most likely to occur at the surface of the water. If shots are not effective in restoring the well production, the next logical step is to use acid.

The acid naturally flows into the crevices from which the water was obtained and will tend to dissolve the deposit and enlarge the crevices. After placing the acide in the well, a definite quantity of water should then be run into the top of the well to force the acid back into the crevices.

Screened wells in sand or gravel are subject to the same mechanical troubles as rock wells, such as loose material in the bottom and holes in casing or screen. The most common trouble, however, is the formation of deposits around the screen and back in the formation, as described above. The two things to remember in undertaking a cleaning job are that the deposit must be loosened and then removed. If the deposit is only loosened but not promptly removed, it will tend to settle back into place with the same clogging as before. The simplest way of loosening deposits is by running an agitator or close-fitting disc up and down in the well. This device has the disadvantage, however, that when a small section of screen has been cleaned, further use of the agitator concentrates the cleaning action on the portion of the screen already cleaned. This disadvantage of the agitator can be overcome by setting a smaller string of pipe in the well with the bottom closed, and a pair of discs on the bottom of the pipe, spaced one to two feet apart, with holes in the pipe between the discs. These discs can be set at any desired point in the screen and then the agitating effect is all concentrated at a given point on the screen.

Compressed air for cleaning is often quite effective. Air should be used with the string of inner pipe as described above, and should be piped so that by simply opening and closing a valve the air is alternately blown back into the formation or the well is pumped by air lift. This method makes it possible to loosen the deposit and remove it a few minutes later.



Method of Applying Acid to Individual Screen Sections—See Text

Another method of cleaning occassionally used is to put 500 to 1,000 pounds of dry ice into the well and, if possible, cap the top of the well. The melting of the dry ice produces violent agitation and considerable pressure but does not remove the deposit. In some cases, backwashing a well from an outside supply of water has produced some improvement, but this method cannot be particularly recommended because it tends to wash the deposit back into the formation. A strong mechanical agitation can be obtained by piping steam down into the well where the rapid condensation provides a violent disturbance. All of the above mentioned methods of cleaning are what might be called mechanical methods, and there is also a mechanical method of preventing or reducing the formation of these deposits. When the pump is installed, if the suction on the pump is sealed tightly to the well screen, a strong backwash is provided each time the pump is stopped and the deposit is removed each time the pump is started. This seal also prevents exposing the water to the air at any time and reduces the tendency to deposit. A very simple seal can be made by building up a cone on the suction pipe made of strips of burlap saturated with tar. This cone should be placed so that it seats tightly in the top of the screen, just as the pump settles down on the base plate, so that the weight of the pump forces the seal into position.

Chemical Methods of Well Cleaning

In recent years the cleaning and developing of wells chemically, using inhibited hydrochloric acid, has been receiving more and more attention. In most cases, hydrochloric acid will dissolve a large percentage of the deposits. Failures are probably due to the fact that the acid could not reach the deposit to work on it. The most important advance in acidizing is by the use of an inhibitor which largely reduces the action of the acid on all metals without reducing its action on the calcareous deposits. Inhibitors range from 80 to 98 per cent effective, but in this selection caution should be used to be sure the inhibitor is nonpoisonous.

Another improvement in acidizing work is the use of a stabilizer. When the acid is first placed in a well it dissolves the "iron" and "lime" deposits rapidly, but as the acid becomes spent the power of the acid to hold the chemicals in solution is reduced, and there is a strong tendency for iron compounds to deposit again. The stabilizer prevents this redeposition and holds the iron in solution once it

has been dissolved. In using acid it is highly desirable to heat the solution in the well. A hot acid solution acts much faster than a cold one and will also dissolve deposits which cannot be dissolved in cold acid.

There is a slow horizontal movement of ground water and in some cases cold acid has been actually carried away from a well before it could complete the job of cleaning. The fast action of hot acid makes it possible for the cleaning to be completed before the flow of underground water tends to carry the acid away.

It is also important in using acid to be sure that the acid reaches the deposit so that it can do its work. It is a mistake to simply dump acid into the top of the well. The acid should be placed through a hose line or pipe, the end of which is moved up through the length of the screen so that the acid is properly distributed. A still better way is to apply acid through the inner piper device with two discs, as previously described, so that the acid can be delivered to any part of the screen desired. Systems have been worked out by which acid can be pumped under pressure through short sections of screen and then circulated, thus providing a washing action. Expanding devices have been used which permit application of heavy liquid pressure at selected points on the screen, which, added to the chemical effect of the hot acid, provides a very positive method of cleaning.

In using any method of acidizing, precaution shrould be taken to protect the men engaged in the work. The acid produces carbon dioxide gas, which comes out of the well and which cannot be detected. The work, therefore, should never be done in an unventilated pit because the workers might actually be "drowned" by carbon dioxide. In most cases the well top should be as open as possible with ample ventilation.

Following the cleaning operations the well should be flushed by pumping and the static level, pumping level, drawdown, output, and yield again determined and recorded.

[Ed. Note: Some success has been had through use of chlorine gas as a means of loosening and dissolving calcareous deposits in wells. The gas pressure serves to surge the water and the chlorine attacks the carbonate, producing carbon dioxide, hypochlorous acid and the soluble chlorides without first forming any hydrochloric acid. Hypochlorous acid is a very weak acid but will further attack the calcareous deposits.]

CHART FOR DETERMINING AREA OF A RING OR CONCENTRIC CIRCLE

Only two dimensions are necessary to determine the area of any ring—the width of the ring, **W**, as shown in the sketch, and the distance **D**, also shown in the sketch. But notice carefully that the distance **D** is *not* the outside diameter, nor is it the inside diameter. It is the distance from the inside edge to the farthest outside edge.

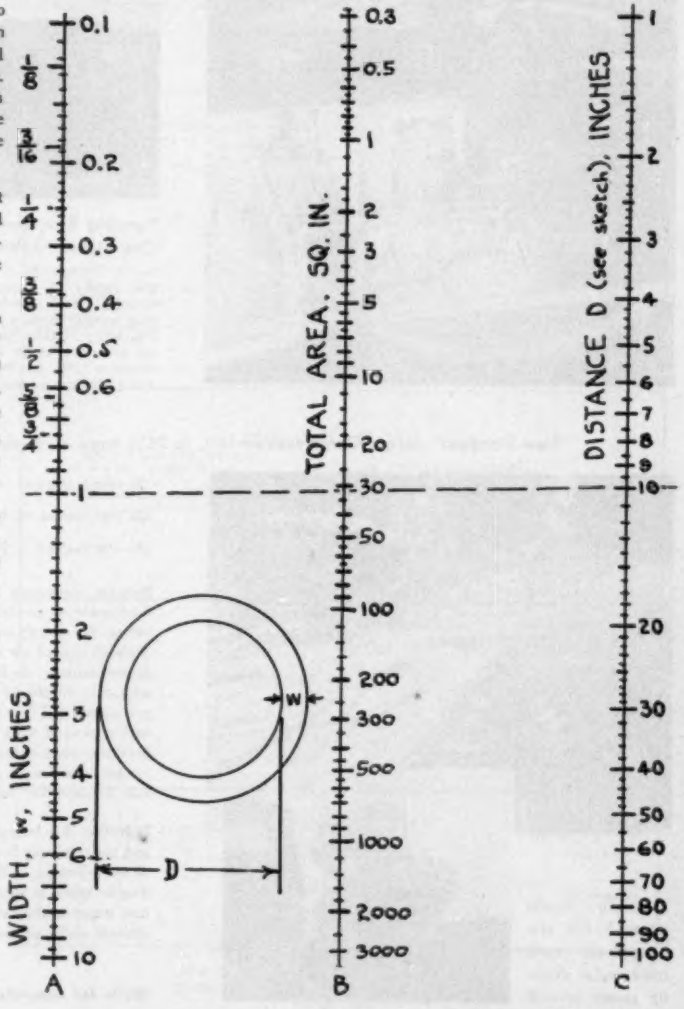
To use the chart simply run a straight line through the width **W** in column **A**, and the distance **D** in column **C**, and the intersection with column **B** instantly gives the area of the ring.

Thus, for example, the dotted line drawn across the chart shows that if the width **W** is one inch and if the distance **D** is 10 inches, the area is a little over 30 inches. Estimating with the eye and reading the scale in the same way that you read a thermometer, it is evident that the area is very clost to 31 sq. in.

If the figures on the chart are not large enough to take care of your problem, simply add ciphers in this way: For example, if the width **W** is 100 inches and the distance **D** is 1,000 inches, the same dotted line will solve the problem. Two ciphers are added in column **A** and two in column **C**, making a total of four ciphers. Therefore, simply add four ciphers to the result in column **B**. The answer is 310,000 sq. in.

Similarly, if the figures on the chart are too large, shift the decimal point over to the *left* in columns **A** and **C**. Then in the "answer" shift the decimal point to the left as many digits as shifted to the left in column **A** plus digits shifted in **C**. For example, if **W** is .01 in. and **D** is 0.1 in., the area is 0.0031 sq. in.

Contributed by W. F. Schaphorst, M.E.
Newark, N.J.



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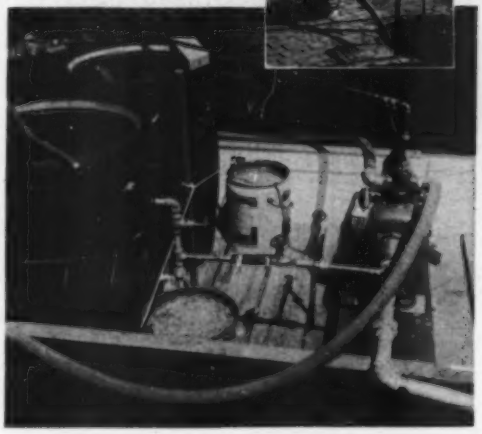
***Manufacturers* of Self-Priming Centrifugal Pumps, Air Compressors, Concrete Mixers**

Distributors in 130 Cities of the United States and Canada

Dewatering pumps from 1½" portable aluminum "Bantam," for manhole pumping and small surface spraying outfits, up to 10" portables of 240,000 gph. capacity for largest excavations, by-passing sewers, big well point installations, etc. All models have doubly-sure fast priming effected by two independent, simultaneous actions, portable or stationary mounting. Pressure pumps available for jet and supply pumping.

Ideal for both dewatering and by-pass pumping

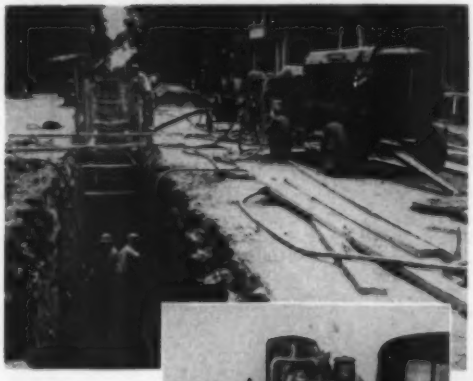
Right: Pumping manhole with Jaeger "Bantam." Below: Spraying for algae control. Courtesy Wisconsin State Board of Health.



Pumping Raw Sewage—One Million Gallons a Day:

As a "temporary" installation, this Jaeger 6" pump ran continuously for 9 months, transferring sewage from a large State University Student Housing Center to a city sewer at a higher elevation 700 ft. away. Intake was 17 ft. below pump.

"New Standard" Jaeger Compressors—15% to 25% more air to do 30% to 40% more work



Travel-Air: Truck-mounted 125 cfm compressor unit, truck engine driven by power take-off.

75 cfm instead of 60 cfm	250 cfm instead of 210 cfm
125 cfm instead of 105 cfm	365 cfm instead of 315 cfm
185 cfm instead of 160 cfm	600 cfm instead of 500 cfm

Because compressor ratings which were established in 1932 are inadequate to operate today's air tools, Jaeger offers "new standard" ratings big enough to run your tools at full pressure and efficiency. With 75 cfm of air at 100 psi a heavy paving breaker or 2 clay spades actually do 30% to 40% more work than when powered with only 60 cfm of air. Each tool strikes hundreds more blows per minute and they are harder hitting blows, backed by full pressure instead of weak 70 lbs. A Jaeger Model 125, behind 2 heavy breakers, gives a comparable increase in production over 105 ft. compressors. Larger sizes are equally adapted for the number and type of tools they are designed to operate.

Note that this increased production is gained with the same men and tools—simply by increased efficiency. The cost, per cubic foot of air delivered, is the lowest of any compressors on the market. Engine speed is automatically regulated to air demand in 125 ft. and larger models which use no more fuel than others when additional air is not required.

Write for complete catalog and name of nearest distributor

DEWATERING MAINS WITH COMPRESSED AIR

By ARTHUR C. KING
Superintendent of Water Works, Taunton, Mass.

HERE in Taunton, Mass., we have adopted the use of compressed air for removing water from mains, developed by Esty and Boardman, and have successfully used the method on pipe of such size that we believe our experience might be of interest to others who may have questioned the value of the scheme for mains of larger sizes. (See sketches.)

An Experience with a 12-Inch Main

It became necessary to relocate about 600 feet of 12 in. cast iron main. Since occupied buildings were supplied from the section to be relocated, it was decided to lay the new main before cutting off the old for salvage.

After the new pipe was laid, the problem was that of making the connections between the old and new as quickly as possible, both on account of regular use and also the reduction in fire protection during the change-over. The section to be drained (about 2500 ft.), lay on an up-grade, as will be seen on the accompanying sketch (a), and hydrants were already in place at the high end and near the low end. The main was shut down, the hydrant near the low end was opened, and the air compressor connected to the hydrant *at the high end*. In a surprisingly short time, perhaps 40 minutes, although it was not timed, water ceased to come out of the hydrant and the main was cut. No water came out through the cut. The old and new sections were connected and the water turned into part of the new main within 4 hours, restoring service to all buildings. The upper end was then cut off and reconnected. Not a bit of ditch pumping was required.

We Try a 16-inch Main

Another large main dewatered with compressed air was of 16 in. cast iron. The length between gates was about 1200 feet—see sketch (b). About 800 feet was on a slight up-grade to a summit, where there was a hydrant. The other 400 feet was on a downgrade to the point of cutting, with a hydrant in that shut-down section just beyond the cut. The low hydrant was opened and the compressor connected to the hydrant at the summit. The water was quickly driven out and the cut made. In this case, apparently some gate was not shut quite tight as a trickle of water occasionally came out, but it was not enough to make trouble for us. We considered this job also a remarkable demonstration of the Danvers method.

On second thought, another hydrant might have been opened to dewater part of the main on the slope back from the summit away from the work, before the cut was made. Then the leakage would have accumulated back of the summit.

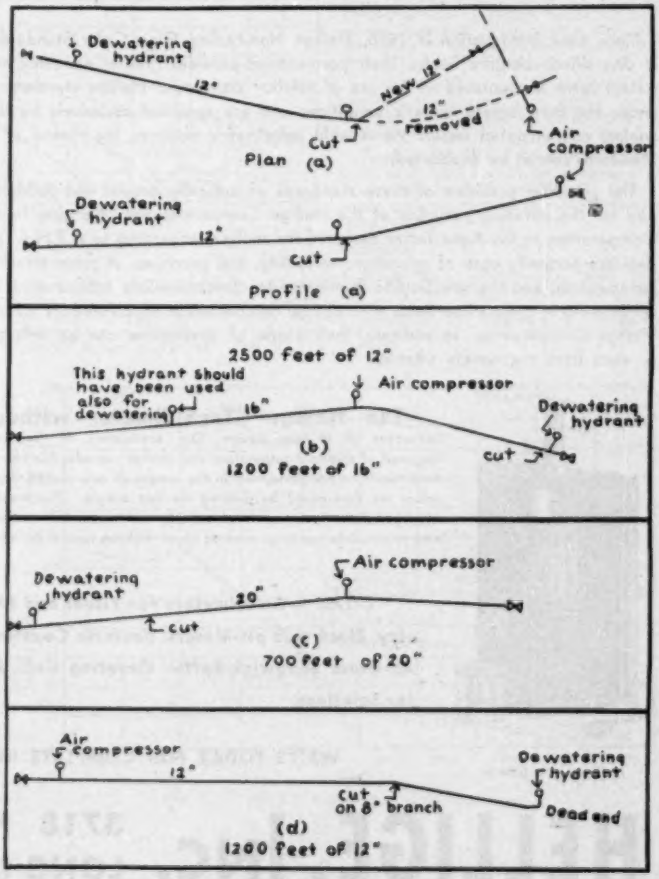
We Do a 20-inch Job

On another occasion we used the air to empty about 700 feet of 20 in. cast iron pipe, sketch (c). The upper end was nearly level for about 200 feet then the pipe sloped down from a hydrant at the summit about 500 feet past the work to be done to a hydrant at the low end. Here again no difficulty was experienced and the water was driven out very quickly, but was not timed.

We also drained about 1200 feet of 12 in. cast iron shown on sketch (d). In this case we cut out and replaced an 8 in. gate valve on a branch main a few feet away, and on an up-grade, from the 12 in. main. The whole job of dewatering, cutting out the old and inserting the new gate was completed in less than 2 hours.

Our compressor is set for a maximum of 95 pounds pressure and starts up when the pressure drops about 10 pounds. We did not note what pressure was held during dewatering, but there was no indication of lack of air or pressure for these lengths of 12 in., 16 in., and 20 in. mains. The rated capacity of our compressor is 110 cubic feet per minute.

The scheme proved its worth very effectively.



Sketches Revealing Conditions in Main Dewatering Experiences Employing Compressed Air

FOR PRECISE pH Control and WATER TESTS

there is nothing like

HELLIGE NON-FADING GLASS COLOR STANDARDS

Hellige Pocket Comparator

Since their introduction in 1926, Hellige Non-Fading Glass Color Standards have proved their unvarying reliability in diversified scientific fields. Their permanence provides greater economy and insures against the variation with resultant error encountered in the use of solution standards. Hellige standards have demonstrated their dependability under the most severe climatic conditions and are specified exclusively by the U. S. Army and Navy for protection against contaminated water. As reliable colorimetric controls, the record of service of our Non-Fading Glass Color Standards cannot be duplicated.

The scientific precision of these standards of optically ground and polished color glass is responsible in great measure for the unfailing accuracy of the Hellige Comparator line. Ranging from Simplex Testers, Pocket and Standard Comparators, to the Aqua Tester designed for analyses according to A.P.H.A. and A.W.W.A. procedure, Hellige Comparators personify ease of operation, versatility, and precision. A prism attachment to bring the comparison colors into juxtaposition, and the new Daylite Illuminator for determinations independent of time or weather, are available. Perfectly uniform comparison fields with optical compensation of colored or turbid samples are a special feature of all Hellige Comparators. In addition, their scope of application can be enlarged by selecting additional color plates or discs from the variety offered.

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The Hellige "Turbidimeter without Standards" is a highly accurate instrument of modern design. Our application of the Tyndall effect to the liquid under test eliminates the need of standard suspensions and assures reproducible results regardless of line voltage fluctuation. Precise determinations are performed in the ranges of zero to 150 p.p.m. SiO_2 and zero to 100 p.p.m. SO_4. Higher values are determined by diluting the test sample. Foolproof and versatile, the Hellige Turbidimeter also is employed for measurements of colloids and suspended matter in general. Convenient, trouble-free operation assures accurate readings even to those without special training in this field.

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HEADQUARTERS FOR COLOR STANDARDS AND COLORIMETRIC APPARATUS

RECOVERING WELL CAPACITY WITH CHLORINE

By W. E. HUSTON

Water Station Foreman, Physical Plant Dept., Univ. of Ill., Urbana, Ill.

IN 1935, two gravel-packed screen wells were constructed for the University of Illinois by a drilling contractor at a cost of about $25,000. At first successful, the flow from the wells, which were known as No. 10 and No. 11, declined rapidly. In March 1940, Well No. 10 was delivering approximately 25 per cent, and Well No. 11 approximately 45 per cent of the original specific capacity.

Diminishing well capacity is not uncommon in this region, but output from these wells had fallen off so greatly that the university supply was threatened. In 1940, as described by White[1], Well No. 10 was treated with acid. Since both calcium and magnesium bicarbonate were found in the well water, it was believed that calcium carbonate deposits might be encrusting the screen. An unsatisfactory increase in capacity, from 24.5 to 38 gpm., made this explanation seem inadequate, however, and it was decided to treat with chlorine as well.

Chlorine treatment raised the capacity from 38 to 50 gpm. per foot of drawdown. This was considered satisfactory even though the increase was somewhat less than that reported by Brown at Eau Claire, Wis.[2] The result seemed to indicate obstruction by an organic growth rather than calcium carbonate, and so the chlorine treatment was used before the acid in Well No. 11.

In Well No. 10, 52 per cent of the gain in specific capacity had been obtained by use of the acid; in Well No. 11, which received the chlorine before the acid treatment, 80 per cent of the gain in capacity was obtained by the chlorine. Figures 1 and 2 portray briefly the original and subsequent treatments and their results.

In 1941, the decline in flow from Well No. 10 was again critical, while flow from Well No. 11 had receded but slightly. The decline in both wells was serious in 1942, but no treatment was undertaken because of a wartime shortage in the chlorine supply.

In 1943, the pumps in both wells were breaking suction. Treatment with chlorine produced better results in Well No. 11 than in Well No. 10. This may have been due to differences in the construction of the wells. The 55 ft. of shutter screen in Well No. 10 is never totally submerged, while the 25 ft. of screen in Well No. 11 is submerged when the pump is idle. In the author's opinion, the results obtained in 1943 reflect the difference in the treatment of the wells in 1940, when acid was applied prior to chlorine in Well No. 10 and chlorine prior to acid in Well No. 11.

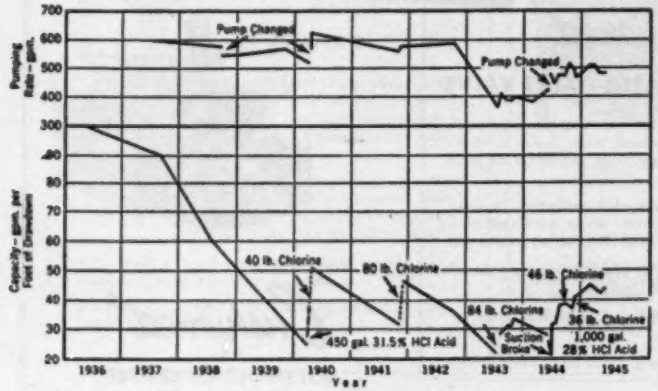

Fig. 1. Recovery of Capacity of Well No. 10

Chlorine and acid were applied in both wells in 1944, and experience seems to indicate that it is possible to overtreat with both. On starting the pump at Well No. 11, after applying acid with the pump in place, no water at all was obtained, but, after starting and stopping the pump at short intervals for several hours, the condition improved. Two months later, the flow from the well was greater than it had been before the acid was applied.

A study of Figs. 1 and 2 indicates that the specific capacity of a well is not a straight-line function, but varies with the rate of pumping.

Some of the minor fluctuations shown may have been caused by variations in ground water levels or interference from other wells at the time the measurements were made.

References

1. White, H. L. Rejuvenating Wells With Chlorine. *Civ. Eng.*, 12:263 (1942).

2. Brown, E. D. Restoring Well Capacity With Chlorine. *Jour. A.W.W.A.*, 34:698 (1942).

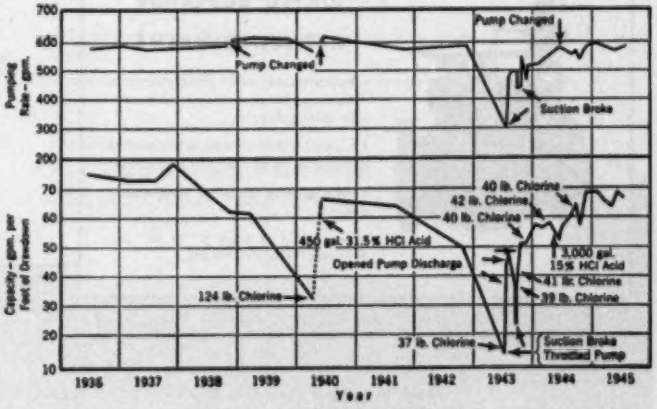

Fig. 2. Recovery of Capacity of Well No. 11

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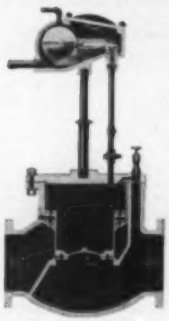

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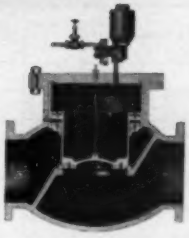

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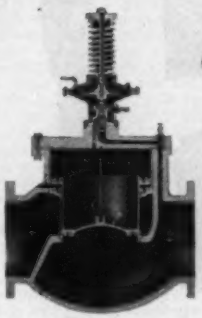

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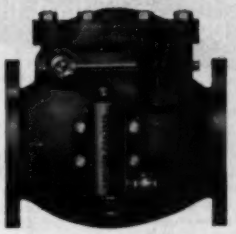

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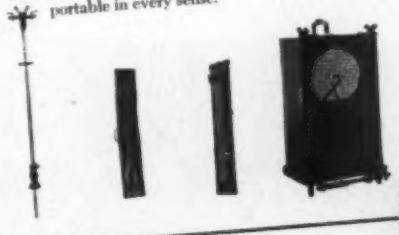

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PRACTICAL METHODS FOR HYDRANT DISCHARGE MEASUREMENTS

By P. S. WILSON

Water Works Consultant, Glen Ridge, N. J.

THE measurements of the discharge or flow from fire hydrants is a common procedure for engineers engaged in testing the fire fighting capacity of a water system. The fact is frequently overlooked that such measurements may also be very usefully applied to many other vital problems with which the operator of a water supply system is regularly confronted. It is likewise not always realized that this work may be performed with but a small expense for equipment and without the need for special technical training.

Actual measurements of the flows taking place in a water distribution system may furnish extremely valuable information to the water works operators. A water distribution system is different from most of the equipment with which other business is conducted. It is buried underground and is not subject to ready inspection. The greater portion of it has not been seen for a generation or more. Its present operator has never seen most of it and almost all he knows of it is what he has been told second or third hand or what he learns from maps and records which are in many cases woefully deficient. What information he does obtain about his system is mostly history,—what it was when it was last seen, years before, not what it is now. It is on account of these conditions that actual tests and measurements are of such great value. One can debate for a long time as to whether a certain valve is open or shut and one may even operate the valve one way or another and still not know much more than before. But if the water in proper quantity flows through that valve and evidences itself on the other side, then the question is settled and there is no more possibility for argument.

There are two principal methods of making field measurements of the flows in water distribution systems. One of these is by means of the Pitot orifice tube inserted through a corporation cock in the side of a main. Such measurements when properly applied are of inestimable value. However, a method of making tests, which is more readily available to the average operator, involves the measurement of hydrant discharges and less time, expense, and equipment are necessary therefore. Measurements so made are not, of course, a complete substitute for Pitot measurements in the pipes, but in many cases they may suffice in themselves to answer the questions at hand. Even if they do not, they always form a valuable guide and adjunct in the making of further and more elaborate tests, if these are later found necessary.

Methods of Measuring Discharge

Measurement of the discharge from an ordinary fire hydrant with sufficient accuracy for most practical purposes is not difficult. By the exercise of care and good judgment, results may be obtained within fairly close limits of accuracy. Rough and ready methods are for the most part amply sufficient, since, for the purposes usually involved, the conclusions arrived at would not be changed by a variation of five or ten per cent one way or the other in the test results. Some of the rather approximate methods to be given must be judged with this fact in mind.

The discharge from a hydrant nozzle is determined from the size or cross sectional area of the emerging stream and from the average velocity of that stream. From these two figures the discharge may readily be computed or may be directly read from tables or diagrams such as those appended to this article.

Measuring Nozzle Diameter

Observation of flow from hydrant nozzles shows that it completely fills the nozzle, as a general rule. Therefore, a simple measurement of the internal diameter of the hydrant nozzle serves to make known the diameter of the stream of water. The entrance to the nozzle from within the barrel may occasionally (particularly in some old styles of hydrants, and hydrants with independently gated nozzles) be sharp enough to cause the emerging stream to be contracted slightly below the size of the nozzle and if such an effect is noted it should be allowed for in the diameter used. The internal diameter of each nozzle should be carefully measured to the nearest one-sixteenth of an inch. An ordinary carpenter's rule is satisfactory for this purpose.

Determining Stream Velocity

The average velocity of the emerging stream of water may be determined in either of two ways. The most common method is by the use of a hydrant Pitot tube which may be inserted into the stream and which transforms the velocity head of the stream into the equivalent pressure head and registers it on an attached pressure gage. This instrument is here pictured. It consists of a hollow blade or "cut-water," shaped so that it may be thrust into the stream without unduly deflecting it. At the end of the blade is a small opening which points directly against the flowing water. The force of the stream striking into this opening creates a pressure in it which is transmitted through the hollow blade and handle to the pressure gage. The gage is an ordinary good pressure gage, except that it should be graduated to read more closely than most gages. The gage most frequently used is graduated every pound and only reads up to about fifty pounds per square inch pressure. It must be a good grade of gage to maintain its accuracy with such close reading. For some purposes it is of value to have a very low pressure gage graduated to half pounds. Sometimes the Pitot tube and the gage are held in place in the stream by a device which clamps over the outside of the nozzle. This device is not ordinarily considered necessary, however, and its use results in greater damage to the Pitot tube if struck by a stone or other object carried by the water. The edges of the blade and the small orifice into it must be kept sharp and symmetrically shaped or the accuracy of the instrument will be seriously affected.

Methods of Determining Velocity of Nozzle Discharge. (Gage on Pitot Tube Held in Stream and Gage Indicating Barrel Pressure Show Practically Same Readings)

In use, the Pitot tube is held in the stream and the pressure read while the small orifice is held at the center of the stram and pointing dirctly against the flow. Occasionally on large nozzles it is advisable to take a rough average of the pressures across the stream at different points horizontally and vertically. In most cases the pressure at the center of the stream will approximate the average pressure. In no case should the pressure very near the edge (within about one-fourth inch) be considered.

The other method of determining the velocity of the stream, and one which has been occasionally found more convenient by the writer, consists merely in placing on one of the hydrant nozzles a cap having an ordinary pressure gage tapped into it then allow the discharge to take place through the other nozzles. Due to the free discharge from the nozzles, practically all of the pressure head remaining in the barel during the flow is transformed into velocity head in the jets. Since that is practically the only source of velocity head in the jets, the ordinary pressure gage indicating the pressure in the barrel will read substantially the same as a gage on a Pitot tube held in a jet. This fact may be readily confirmed by trial. In this way the discharge of a hydrant may be measured with fair accuracy, without the Pitot tube, merely by the use of a pressure gage, the gage reading being used to compute the discharge in the same manner as if it were a Pitot tube reading. The same type of gage should be used for this method as described above for the Pitot tube. Any pressure gage may be used, however, the accuracy of the results depending upon the accuracy of the gage and the closeness of the graduations and readings.

An accompanying illustration shows a Pitot tube with gage being held in the

Hydrant Pitot Tube with Gage

stream from one hydrant nozzle while a pressure gage on the other nozzle is at the same time indicating the pressure in the barrel. This illustrates the two methods of determining the velocity head of the stream. Unfortunately the photograph does not make it possible to see what the gages are reading; actually they show the same—18 pounds per square inch. In using the Pitot at low velocities, where a quarter pound makes an appreciable difference, the instrument should be held horizontally so that the pressure gage will be at the same elevation as the nozzle.

With the same accuracy of gage reading the only inaccuracies in the second method as compared with the use of the Pitot tube are in the fact that there is a slight loss of head in entering and flowing through the nozzle and in the assumption that the velocity head in the barrel at the point of pressure reading is zero. This latter assumption is justified because the velocity in the barrel is low compared to that in the jet and the pressure reading is taken opposite or above the other nozzles which are discharging. In any case, as before mentioned, trial will show that the results are in general substantially the same for both methods. If the hydrant Pitot tube is at hand, its use is best and most convenient; the availability of the other method, however, should always be borne in mind.

The pressure gage on one nozzle, of course, prevents the use of that nozzle for the discharge of water. This is not always a disadavantage, however, particularly when the hydrant is equipped with a steamer nozzle which may be used for attaching the gage.

A fact which may readily be perceived from the foregoing is that, when measuring the velocity with a Pitot tube, readings need only be taken (except as a check) in one of several nozzles discharging simultaneously because readings in all of the nozzle streams should be practically alike.

Computation of the Flow

By the measurement of the nozzle diameter we now have obtained a diameter of the stream of water, and from the pressure gage reading we have obtained a figure which bears a known relation to the velocity of the stream. The formula for the discharge may now be readily derived from the fact that:

Discharge = (area of stream) × (average velocity)

If d = the internal diameter of the hydrant nozzle in inches, then, using the formula for the area of a circle, the area of the stream is $\frac{3.14xd^2}{4}$ square inches. For convenience in computing, this is divided by 144—the resulting formula being $0.00545xd^2$ to obtain the area of the stream in square feet.

The pressure gage reading, in pounds per square inch (p) is changed to feet of water head by multiplying it by 2.31. A fundamental hydraulic formula states that the velocity of the stream of water is equal to the square root of the pressure head multiplied by the square root of two times the acceleration of a falling body, due to gravity. This latter (g) is a constant and is equal to 32.2 in foot and second units. Therefore:

(a) Velocity of the stream is feet per second =

$$\sqrt{2.31} \times p \times \sqrt{2 \times 32.2} = 12.2 \times \sqrt{p}$$

(b) Discharge in cubic feet per second =

$$0.00545 \times d^2 \times 12.2 \times \sqrt{p} = 0.0665 \times d^2 \times \sqrt{p}$$

(c) Discharge in gallons per minute =

$$29.9 \times d^2 \times \sqrt{p}$$

The velocity of the stream of water as determined by either of the two methods described does not take into account the very low velocity of the stream around the edges where it is held back by its contact (friction) with the nozzle. To make allowance for this, as well as to allow for a possible slight contraction of the jet, it is necessary to make use of a coefficient in computing the results. This coefficient has been determined experimentally by checking hydrant flow measurements against other and more accurate means of metering the flow. The coefficient should, theoretically, be different for different hydrants, but it is sufficiently accurate for the purposes and means of measurement under discussion to use an average figure which has been found by experiment to be about correct for most cases. The figure most generally used is 0.90 and thus the formula derived above is modified as follows:

(d) Discharge in gallons per minute =

$$0.90 \times 29.9 \times d^2 \times \sqrt{p} = 26.9 \times d^2 \times \sqrt{p}$$

For convenience the 26.9 may be rounded off to an even 27 without introducing an error of importance, resulting in the completed formula:

(e) Discharge in gallons per minute =

$$27 \times d^2 \times \sqrt{p}$$

in which d = diameter of nozzle in inches and, p = gage reading in lbs. per sq. inch.

Tables and Charts

From this formula tables may be constructed in which the discharge is given for each combination of diameter of nozzle and Pitot pressure head and from which the result of the measurement may therefore be read directly without computation. A specimen is shown in Table 1.

TABLE 1

Hydrant Discharge*

Gallons per minute = 27 d^2 / p

Gage Reading—Hydrant nozzle diameter in inches [d]

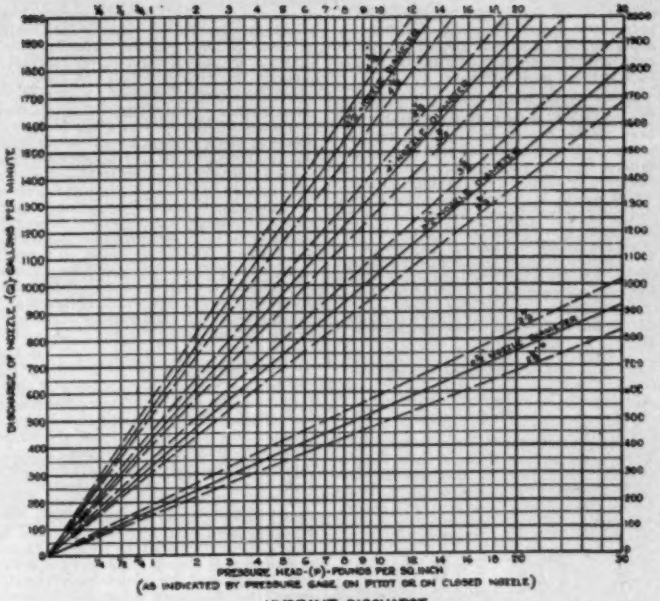
p	2	2⅛	2¼	2⅜	2½	2⅝
¼	70	80	80	80	90	90
½	100	110	110	120	120	130
¾	120	130	140	150	150	160
1	140	150	160	170	180	190
1¼	160	170	180	190	200	210
1½	180	190	200	210	220	230
1¾	190	200	210	220	230	250
2	200	210	230	240	250	260
2½	230	240	250	270	280	290
3	250	260	280	290	310	320
3½	270	280	300	320	330	350
4	290	300	320	340	350	370
4½	310	320	340	360	380	390
5	220	340	360	380	400	420
5½	340	360	380	400	420	440
6	350	370	390	410	430	460
6½	370	390	410	430	450	470
7	380	400	420	450	470	490
7½	400	420	440	460	490	510
8	410	430	450	480	500	530
8½	420	440	470	490	520	540
9	430	460	480	510	530	560
9½	440	470	490	520	550	570
10	460	480	510	530	560	590
11	480	510	530	560	590	620
12	500	530	560	590	610	650
13	520	550	580	610	640	670
14	540	570	600	630	660	700
15	560	590	620	650	690	720
16	580	610	640	670	710	740
17	600	630	660	700	730	770
18	610	650	680	720	750	790
19	630	660	700	700	770	810
20	640	680	720	750	790	830
22	680	710	750	790	830	870
24	710	750	790	830	870	910
26	740	780	820	860	900	950
28	760	810	850	890	940	980
30	790	830	880	920	970	1020

*Discharges shown to nearest 10 gals. per min.

The discharges in this table are given to the nearest ten gallons per minute. Tables may be made up very conveniently to fit in field note books. For special purposes they may be abbreviated or enlarged either in range or in closeness of reading.

Another method of handling the formula is by the use of diagrams. A particularly convenient form for such a diagram, which the author has never seen in use elsewhere, accompanies this article. In this diagram measurements horizontally from the origin or zero are proportional to the square root of the Pitot pressure head, $\sqrt{p}$. Measurements vertically are proportional to the discharge of the hydrant nozzle in gallons per minute. An inclined straight line passing through the origin then represents each value of the nozzle diameter, (d). A heavy line is drawn for each size of nozzle in use using the theoretically correct value of d,— for example $2\frac{1}{2}$ inches for an ordinary hose nozzle. Light lines are then drawn on the diagram below and above the first ones representing ¼-inch undersize and oversize of each nozzle. From these three lines values for each 1/16 to ¼-inch under and over the nominal sizes may readily be read on the diagram. This covers the usual variation of the nozzles. It is to be noted that the horizontal distances on the diagram are not directly proportional to the pressures but to the square roots of the pressures. This results in uneven spacing of the figures, but by so constructing the diagram the lines representing the nozzle diameters may be drawn straight, whereas otherwise they would be curved. The uneven spacing of the pressure lines makes accurate interpolation difficult, and therefore enough lines are drawn on the diagram to make this unnecessary.

Having made a discharge measurement this diagram is used as follows: Pick the vertical line representing the Pitot pressure reading, follow it up or down to where it crosses the line representing the actual measured internal diameter of the nozzle, estimating where that line would be if the correct one is not on the diagram. Then follow the horizontal lines to right or left and read the discharge on the vertical scale.


DISCHARGE OF NOZZLE (Q) GALLONS PER MINUTE
PRESSURE HEAD-(p)-POUNDS PER SQ. INCH
(AS INDICATED BY PRESSURE GAGE ON PITOT OR ON CLOSED NOZZLE)
HYDRANT DISCHARGE
(Q = 27.4 d² √p)

Hydrant Discharge Diagram. (Courtesy, Community Water Service Co.)

Comments

A careful study of the formula and the tables and diagrams leads to a number of important observations on the carrying on of this work. When the Pitot pressure reading is low, a slight difference in the reading will result in a very large percentage difference in the result, whereas at higher pressures a half pound or even a pound does not make much difference. For instance the difference between 1 and 2 pounds per square inch makes about 40 per cent difference in the discharge while the difference between 10 and 11 pounds per square inch makes only about 5 per cent difference. This fact is the reason for making the pressure differences in the table and diagram smaller in the lower range. It also indicates the necessity for making very careful Pitot pressure determinations in the field, particularly at low pressures. Gages should be closely graduated as before mentioned and should have at least three inch dials. On particular work they should be calibrated with a dead weight tester before and after using and corrections applied to the readings if necessary. Gages should be handled gently and with care so as to maintain their accuracy. Since they will probably not read as high as the static pressure in the mains, care should be taken when taking pressures on a closed nozzle not to subject them to too much pressure. Other gages must, of course, be provided for taking the direct main pressures.

Emphasis must be placed on the necessity for keeping the connections between the Pitot blade and the pressure gage absolutely tight. A very slight leak, in fact only a drip which in the general splashing may not be noticed, is sufficient to make the reading considerably in error. The connections should be made up tightly with wrenches and should not be loosened in order to turn the gage into a more convenient position.

It will be noted that a 1/16-inch difference in the diameter of the nozzle makes a much greater percentage difference at high discharges than at low ones. This is the opposite from the effect of the pressures. In spite of this is will usually result in greater accuracy to use as few and as small nozzles as possible in a measurement. The use of steamer nozzles is advised only on work where approximate results would be satisfactory. Further experiments may show that a slightly different coefficient should be used in computing the discharge of the larger sizes of nozzles.

Fire Flow Tests

The making of fire flow tests is the most obvious use to which hydrant flow measurements may be put. Such tests consist in the determination of what amount of water is available at a given hydrant, or at a given group of hydrants, for use by the fire department. This test is the one usually made by the engineers of the National Board of Fire Underwriters in rating a system for fire protection. So much has been written on such tests that they need be only mentioned here. Simultaneous readings are taken on as many hydrants in a group as are needed in order to develop the capacity of the system. At the same time a record is kept at an adjacent hydrant (not discharging), of the residual pressure. From a set of such readings the discharge capacity of the system at that point with any residual pressure may be known.

The residual pressure mentioned above is the pressure remaining in the mains during the time that a flow test is taking place. This pressure is determined by the readings of a pressure gage attached to a hydrant which is *not* discharging but which is located by and, if possible, on the side opposite to the direction from which the flow is coming. The actual capacity of the distribution system at a given point is usually considered to be the discharge with the residual pressure drawn down to some stated figure. By this method the results of flow tests at different points and on different systems are made comparable. When fire engine pumpers are to be used then the maximum capacity of the system may be considered as the discharge with the residual pressure drawn down to 20 lbs. per sq. in. If reliance is placed on direct hydrant pressure for the hose streams then the residual pressure can not be drawn down nearly so low and the maximum capacity of the system at such higher residual pressures will be less. Sometimes the capacity of a system is referred to as the discharge with a drop in pressure of 20 lbs. per sq. in., in other words, with a residual pressure 20 lbs. per sq. in. less than the original pressure before the hydrants were opened. This will usually be a very different figure from the capacity at 20 lbs. per sq. in. minimum residual pressure.

It is usually difficult or impossible to make a flow measurement at exactly the rate of discharge which will result in the residual pressure desired. It is customary, therefore, to make the measurement at some rate of discharge as near as convenient to that producing the effect desired and then to compute what the dis-

charge would have been at the residual pressure desired. This may be done by applying the fact that the discharge is approximately proportional to the square root of the drop in pressure.

If, for example, the original pressure in the mains before opening the hydrants had been 56 lbs. per sq. in., and the residual pressure during a flow of 2680 gallons per minute had been 32 lbs. per sq. in., then the drop in pressure during that flow was 24 lbs. per sq. in. Suppose now that it were desired to know in this example what the discharge would have been with a residual pressure of 20 lbs. per sq. in. The drop in pressure in that case would have been 36 lbs. per sq. in. It is then merely necessary to multiply the measured discharge (2680 gal. per min.) by the square root of 36 (which is 6.0) and divide by the square root of 24 (which is 4.9).

$$\frac{2680 \times 6.0}{4.9} = 32.80 \text{ gal. per min.}$$

which would have been the discharge at 20 lbs. per sq. in. residual pressure.

If Q_1 is the measured discharge with a drop in pressure of D_1; and Q_2 is the discharge which would have taken place with a drop in pressure of D_2 then the above method may be stated in a general formula as follows:

$$Q_2 = Q_1 \times \frac{\sqrt{D_2}}{\sqrt{D_1}}$$

This method, as stated before, is only approximate and it should not be considered very reliable if the drop in pressure at the measured discharge is very greatly different from the drop in pressure desired. The method is, however, entirely satisfactory for most practical purposes.

Fire flow tests may indicate not only whether the system has the desired capacity or not, but they may be amplified to give information as to what work should be done to increase the capacity. For example, by taking a record of the pressures in the system during the flow test at various points progressing back toward the source of supply, it may be conclusively shown whether a restriction is in the principal supply mains or whether it is in the local mains adjacent to the test. By cutting out certain mains during the test still further information may be gained as to the actual conditions existing; closed valves or other obstructions, defective hydrants, or large leaks may be discovered and located. This work opens up a great field for the display of ingenuity on the part of the operator since the exact procedure is subject to unlimited variation and depends upon the arrangement of the particular system under test.

Uses for Hydrant Flow Measurements

There are many other varieties of tests, measurements and experiments which may be performed on a distribution system through the use of hydrant discharge measurements. They may be used in making determinations of the friction coefficient in certain mains of the system. By isolating a stretch of pipe so that the feed into it is from one end only, a flow through it may be created which can be measured at its discharge from a hydrant or hydrants at the end of the section under test. If pressures are taken simultaneously during the flow at intermediate hydrants or other connections of known elevation along the main, then, from the data so obtained, the loss of head and the friction coefficients of each section may be computed. Obstructions or closed valves may also be located through the unequal drops in pressure in different sections along the line when such difficulties exist.

Such tests are of value in determining the necessity for or advisability of cleaning a main and likewise, in determining the effectiveness of the cleaning after it has been performed. If they are made periodically after cleaning, valuable data will be obtained as to the speed and degree of the return of roughness in the pipe, thereby indicating the true value of the cleaning and the advisability of recleaning or of cleaning other mains. Also the efficacy of corrosion control procedures will be disclosed and the results of changes evaluated.

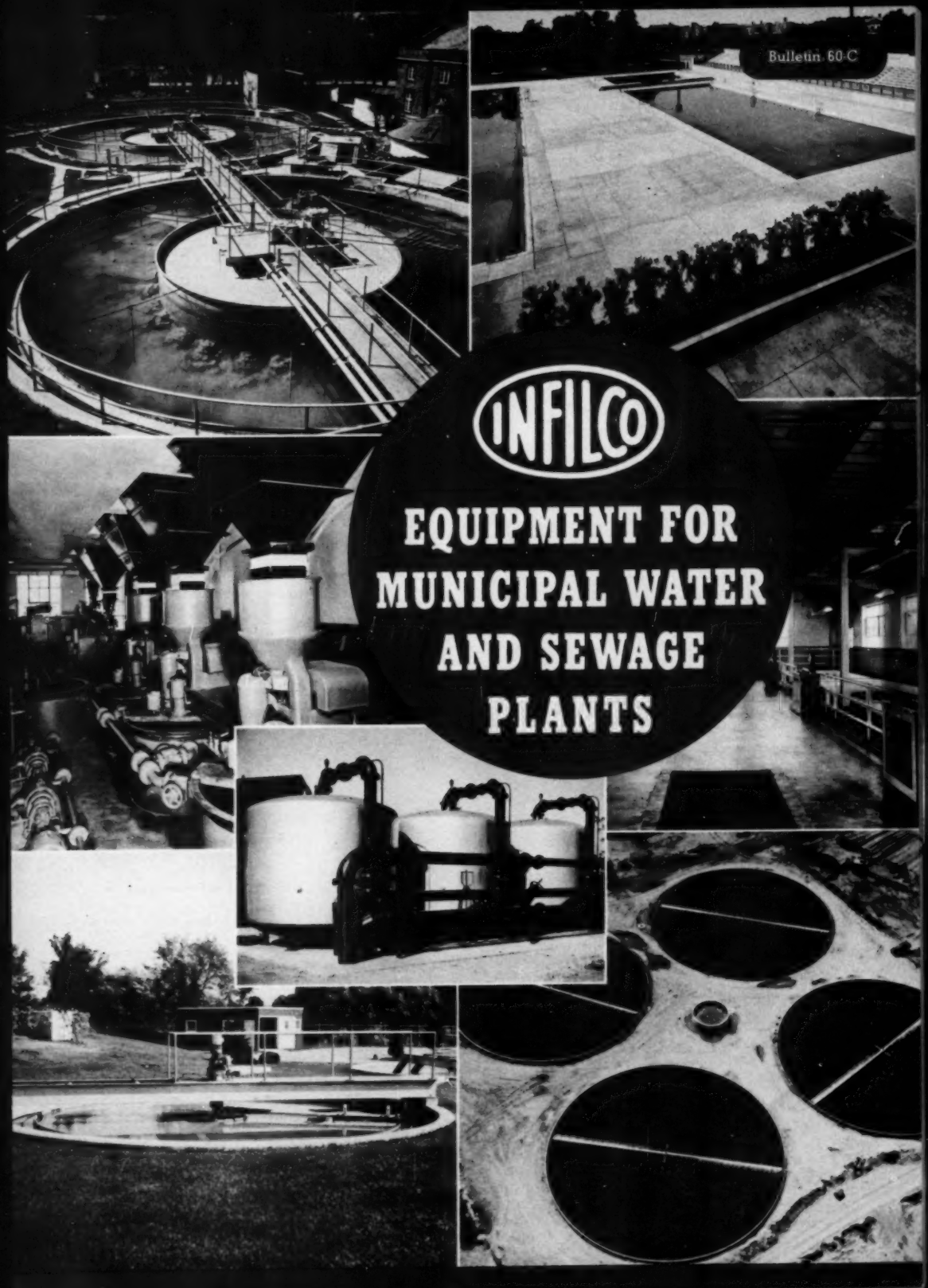
In those cases where a company's records are inaccurate, loss of head tests may be quickly made to provide an accurate indication of the size of any main which is in doubt.

When flushing out sediment or other deposits from the pipes of a system it is of great value to make a rough check of the discharge of the hydrants or blow-offs in use in order to be certain that a sufficient velocity has been created in the main or mains supplying that point to properly clean them out. From 4 to 6 feet per second is usually considered the minimum that will effectively flush out a main, so that the material remaining will cause no further difficulty by being stirred up by normal flows.

It is difficult to foresee all of the benefits which may come of making tests such as these on a distribution system. One of the greatest benefits is that, no matter what their nature, they will ordinarily result in an unusually thoughtful and detailed consideration of the system on the part of the men who are operating it. The effort to interpret and account for results, and the resulting further tests, will frequently uncover unsuspected conditions quite different from those which originally suggested the tests.

Degree of Hardness and Soap Consumption

Grains ($CaCO_3$) per U.S. Gallon	Parts per Million	Pure Soap Consumption (Lbs. per 1000 gals.)	Grains ($CaCO_3$) per U.S. Gallon	Parts per Million	Pure Soap Consumption (Lbs. per 1000 gals.)
1	17.1	1.3	21	359.1	28.4
2	34.2	2.7	22	376.2	29.7
3	51.3	4.0	23	393.3	31.0
4	68.4	5.4	24	410.4	32.3
5	85.5	6.7	25	427.5	33.7
6	102.6	8.1	26	444.6	35.0
7	119.7	9.5	27	461.7	36.3
8	136.8	10.8	28	478.8	37.7
9	153.9	12.1	29	495.9	39.0
10	171.0	13.5	30	513.0	40.5
11	188.1	14.8	31	530.1	41.8
12	205.2	16.2	32	547.2	43.2
13	222.3	17.5	33	564.3	44.4
14	239.4	18.9	34	581.4	45.7
15	256.5	20.2	35	598.5	47.1
16	273.6	21.6	36	615.6	48.5
17	290.7	22.9	37	632.7	49.8
18	307.8	24.3	38	649.8	51.2
19	324.9	25.6	39	666.9	52.5
20	342.0	27.0	40	684.0	53.8


Bulletin 60-C
INFILCO
EQUIPMENT FOR
MUNICIPAL WATER
AND SEWAGE
PLANTS

INFILCO WATER CONDITIONING EQUIPMENT

Infilco has for more than fifty years specialized in the design and manufacture of all types of equipment for municipal water conditioning plants—softening and filter plant equipment, recarbonators, chemical feeders and proportioners, gauges, hydraulic controls, etc. By providing a complete range of water conditioning equipment, Infilco offers the user the important advantage of undivided responsibility.

A complete laboratory and a staff of competent engineers are available for making recommendations and reports to the consulting engineer or his client. It is, of course, intended that this service shall cooperate with, and not conflict with, the work of the engineer.

WATER SOFTENERS

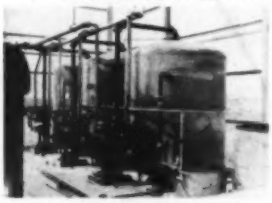
There are Infilco water softening plants for every requirement and for every type of water. You may depend upon our unbiased recommendation for your particular needs. Thousands of softening plants of various types in use the country over testify to the continued satisfactory service rendered by these units.

ACCELATOR® FOR SOFTENING, CLARIFYING AND STABILIZATION

The Accelator for water softening, clarification, or stabilization is one of the most important water treatment developments in recent years. It is the most outstanding of the modern high-rate treating plants, as evidenced by the more than 1100 Accelators now in service. It replaces in a single basin the old style separate processes of mixing, coagulation and sedimentation. Not only does it save up to 80% in space, but it also produces a cleaner, more stable effluent than is available with any other type. This means greater chemical economy, longer filter runs, easier operation, and less maintenance. The principle of slurry recirculation and dynamic separation are unique with the Accelator.

ZEOLITES AND ZEOLITE SOFTENERS

Infilco zeolite softeners are of either pressure or gravity type, and are built in sizes to meet any capacity requirement. Controls are furnished for either manual, semi-automatic, or fully automatic operation as desired.



A variety of Infilco zeolites is available, and the selection of type to be used will depend upon the characteristics of the water to be softened and upon requirements. All Infilco zeolites are capable of quick regeneration, considerable overload capacity and operation at high rates of flow.

CHEMICAL FEEDERS

Infilco dry chemical feeders provide means for accurate volumetric and gravimetric measurement of powdered, granular, or lump materials such as lime, alum, soda, carbon, etc. Capacities are from a fraction of a pound to hundreds of

pounds per hour. Solution and wet chemical feeders are available in numerous types and many sizes to meet any requirement for accurately measuring and feeding chemical solutions and slurries.

LIME SLAKERS

The Infilco lime slaker combines in one continuous, automatic process the economical feeding and slaking of quick lime, followed by the preparation and delivery of a correct milk of lime mixture for water treatment.

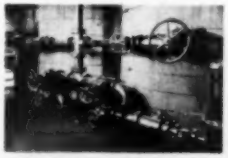
PROPORTIONERS

Infilco proportioners are recommended for those plants which will treat water at varying rates of flow. Their application is primarily in controlling the rate of chemical feed so that it is always directly proportional to the flow of water. There are various types of Infilco proportioners to satisfy different requirements.

PRESSURE AND GRAVITY FILTERS

Clean, clear water, essential for municipal supply, is assured by Infilco pressure or gravity filter plants, in capacities from a hundred gallons per day up.

The design of every Infilco filter plant is based upon sound engineering principles backed by over fifty years of experience in equipping many hundred municipal water works, and in building tens of thousands of industrial filters.



TRANSFER SWITCHES, OPERATING TABLES, ROBOTROL® AND SAMPLING TABLES

Infilco transfer switches provide finger-tip control of hydraulically operated mechanisms. They meet every requirement

of 4-way plugs or piston cocks without their inherent disadvantages. Extreme compactness is obtained by grouping all four separate valves in one body, along with pressure and waste passages.

Infilco operating tables offer both utility and a pleasing appearance. They provide centralized and simplified control for a number of hydraulically operated valves, and at the same time furnish an attractive mounting for the control levers, indicators and gauges.

The Robotrol is a robot filter or softener operator. It backwashes (or regenerates) and returns the unit to service—automatically, efficiently, and without supervision.

Sampling tables furnish a visual check on the condition of raw, treated and filtered water.

INFILCO FILTER UNDERDRAINS

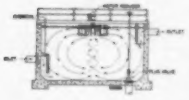
Wagner filter underdrains provide a primary distribution system of a manifold and laterals on wide centers, with distribution orifices along their undersides; and a secondary system of Wagner precast blocks fitting between the laterals. The system fills every requirement for perfect wash water distribution. With manifold and laterals of Transite (an asbestos and Portland cement product) this underdrain is practically everlasting.

CONTROLLERS

Infilco rate of flow controllers automatically maintain uniform rates of flow, prevent dangerous wash rates, and are notable for their accuracy, low loss of head, reset and rate setter features. Infilco water level controllers operate hydraulically controlled valves to maintain basin or tank levels within definite limits.

VORTI-FLOC®

The Vorti-Floc promotes economy and efficiency in the chemical treatment of water and sewage. It causes applied chemicals to be utilized fully by bringing the products resulting from chemical reactions into intimate contact with the liquid undergoing treatment.



Rolling the liquid over gently and repeatedly provides a most effective contact between coagulating substances and solids. Finely divided particles are brought together into larger masses which are themselves prevented from depositing by the moving liquid which continually sweeps up the bottom of the basin. All of the chemicals applied are usefully employed in coagulating the solids, and waste is avoided. The solids coagulate and collect rapidly, clarifying the liquid, and aggregate into masses having proper subsiding values. The Vorti-Floc impeller has been proved by its use in hundreds of Accelators.

RECARBONATORS

Infilco recarbonators are available for water softening plants where lime is used. This process of stabilizing lime-softened water is effective and inexpensive. The equipment provides for producing, cooling and scrubbing, compressing, drying and applying the carbon dioxide gas to the softened water.

GAUGES AND INDICATORS

Infilco illuminated indicators and indicating, recording, rate of flow, loss of head, and liquid level gauges, furnish visible and permanent evidence of hydraulic conditions, guide plant operation and provide required records. There are various types of Infilco gauges available, with both table and pedestal mountings, to fill every requirement for this kind of equipment.

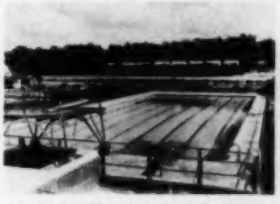
AERATORS

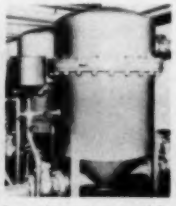
To permit selection of the proper type of aerator to meet conditions of head and space available, character and quantity

of water to be handled, and the results desired—Infilco offers its MultiCone, forced draft, coke tray, floating cone, adjustable cone and cascade aerators.

STELLAR® FILTER RECIRCULATING SYSTEMS FOR SWIMMING POOLS

Stellar Filter Recirculating Systems are outmoding conventional sand filter installations because of smaller space requirements, lower installation costs, and saving of wash water. Stellar Filters are the original diatomite filters to be used on pools and their performance establishes the standard by which





this type of filter is judged. Stellars produce clearer water with less care and without skilled operators, and they cannot be injured by neglectful operation. Other Infilco pool equipment includes: control and regulating equipment, chemical feeders, pool cleaners, pool fittings, testing outfits, hair and lint catchers, sterilizers, heaters, recirculating pumps, and additional specialties.

INFILCO SEWAGE TREATING EQUIPMENT

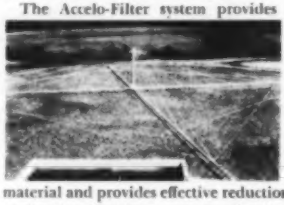
Following are typical examples of Infilco equipment for chemical, biological and mechanical sewage treatment processes. Chemical feeders, slakers, automatic proportioners, and flow meters, common to both water and sewage plants, are described on preceding pages.

AUTOMATIC SEWAGE SAMPLERS

Infilco automatic sewage samplers collect and composite sewage samples at any desired interval from one to twenty times per hour. They are designed to permit sterilization and include a refrigeration unit if desired.

ACCELO® FILTER SYSTEMS

The Accelo-Filter system provides a new and improved method for treating sewage and organic wastes by constant, *direct* recirculation through the trickling filter. This results in repeated inoculation with freshly aerated material and provides effective reduction of the organic content of the biological filter at a considerably higher dosage rate.



ROTARY DISTRIBUTORS AND DOSING SIPHONS

Only Infilco rotary distributors offer so many important refinements such as full opening arm end gates, mercury seal with protective seal ring, with low operating head requirements and uniformity of distribution. Aero-Spray Nozzles provide a fan-shaped variable spray which assures optimum coverage and maximum aeration. Infilco dosing siphons insure perfect operation of distributor mechanism at all flow rates.

CLARIFIERS

Infilco Types WS and PD Clarifiers obtain a perfect balance of the conditions necessary for efficient operation. These Clarifiers are designed with curved scraper blades that gently concentrate and remove settled material with practically no disturbance of the liquid. Accordingly, retention periods may be selected to avoid both septic action and excessive surface scum formation.

VORTI-MIX® AERATORS

The Vorti-Mix Aerator is a combined mechanical mixing and air dispersion system which provides more economical aeration for activated sludge treatment. It is not subject to clogging and hence is cheaper to operate and maintain than other diffusion systems.

DAYTONA BEACH PROCESS PLANT

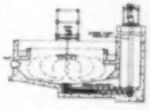
The Daytona Beach Process Plant is one of the most significant new developments in the field of sewage treatment. It is based on the ability of water softening plant sludge (or other similar material) to remove oil and greases and colloidal organic matter. Utilizing the Accelator (Page 2) with Vorti-Mix Aerator, the process accomplishes BOD reduction as high as 80% and produces an effluent averaging only 10 ppm suspended solids, at but a fraction of the cost and space of other primary treatment methods.

AERO-ACCELATOR

The Aero-Accelator with Vorti-Mix Aerator combines intensive aeration with Accelator type circulation to set up the proper conditions for rapid biological oxidation and clarification of liquid wastes or sewage. Dispersion of air throughout the entire mass of "activated slurry" permits a much shorter treatment time than is possible with conventional methods.

VORTEX GRIT REMOVERS

To protect treatment plant equipment, and to reduce the non-digestible load on the plant, Infilco offers the Vortex Grit Remover. The Vortex Circulator produces controlled velocities which are always right for selective separation and collection of clean grit.

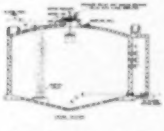


GRIDUCTOR®

The Griductor, for sewage screening and cutting, offers the unique advantages of straight channel installation plus double-end adjustable cutter teeth which may be resharpened and realigned for longer effective life. It is easily installed in existing channels and no difficult framework is required for new construction.

DIGESTERS

Infilco's Type VC Digester provides better digestion and better gas generation. The Vortex Circulator sets up a controlled disturbance in the upper part of the tank to prevent excessive scum formation and to provide the agitation and mixing necessary for optimum digestion. The difficulties of excessive scum formation are avoided and the benefits of proper mixing, circulation and temperature control are obtained with the VC Digester.



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INFILCO INCORPORATED

TUCSON, ARIZONA

WATER, SEWAGE AND TRADE WASTE TREATMENT EQUIPMENT SINCE 1894

SMALL METER SHOP

By ROGER W. ESTY

*Former Supt. Water and Sewer Board, Danvers, Mass.**

THE Town of Danvers, situated in the northeastern parts of Massachusetts, is a farming and industrial community, with considerable historical background.

The water system, started back in 1876 with some twenty miles of pipe and about 500 services, today covers 67 miles and has 3,200 metered services. Consumption started off with about 120,000,000 gallons per year and increased to an annual consumption of 550,000,000 gallons during the 1920's. Metering, which was begun in 1922, has caused water waste and total consumption to drop some every year until now Danvers uses only about 360,000,000 gallons annually.

For years, while water consumption was decreasing and metering was increasing, revenue kept increasing until it became permissible to reduce the service charge 20 per cent. Later the meter rate was cut 25 per cent.

All of this is the result of planned metering. We had no meter testing room in which to test, store, and maintain meters. Most of the meters—70 per cent—had only been in about five years, and we felt it was becoming necessary to build and equip a modern, up to date testing room to properly maintain them.

Compact New Meter Shop

Well, what is different with our testing room than what you may have? It may be different in one respect, and that is, we started off with everything new. The Board decided that they would build and equip an up to the minute meter room within our present shop building. For the purpose $1,500 was voted to equip it.

Outside of our commercial meters we only had about 1,000 meters from 1922 to 1934. Then we started to install a few hundred each year until we had 3,200 meters in service by 1938.

The pictures accompanying this article illustrate our present set-up which we feel meets our needs in a satisfactory and efficient manner.

The room is 21 feet 3 inches long by 11 feet wide with Homasote wallboard walls, stained hardwood floor, three windows equipped with venetian blinds and two doors. So, first of all, it is light and airy. For artificial light it is lighted by fluorescent lights.

We installed a three meter Ford testing machine and Ford's Testerate device, which regulates the testing flow in gallons per minute, a 10 cubic foot tank and 1 cubic foot tank.

Three-Unit Ford Testing Machine

Equipped with flow indicating "Testerate" unit, above, discharging into calibrated 10 cu. ft. and 1 cu. ft. measuring tanks. This set up is a "honey."

In the corner of the room, between the meter testing machine and bench, we constructed a wooden washing sink, which is 3 feet 4 inches by 1 foot 8 inches by 36 inches high.

The bench is 12 feet 4 inches and 2 feet 5 inches wide and is 3 feet high. It is constructed out of oak and is covered with a steel top. It has a meter-holder on the end over the sink, where the meters are taken apart, and a small vise is located near the same end. At the other end is a portable drill press and a portable grinding and brushing machine.

Under the bench top near the sink is a drawer for the every day tools. Then an empty space to sit before, so a man's legs can go comfortably under the bench. Under this section is our air line hose coming in from the garage. We find the air hose a highly important and useful part of meter shop equipment because it is very essential to have air to properly clean and dry out the disc chamber for proper fitting. Also air is useful for operating a meter for any purpose, particularly the "running in" of discs.

Convenient method of storing meter parts. We call it our "baker's wagon," after which it was patterned.

The wash-sink in a corner; meter holder for dismantling; cleaning gadgets and handy roll of paper towels. The ivy adds a touch.

Work bench with record file and desk in corner. Portable drill press, grinding and brushing machine—and plenty of tools and light.

Views of the Danvers Meter Shop

*Now associated with Water Works Supply Co., Lynn, Mass.

DANVERS WATER WORKS

Make

Number | Order No.

Reading B. T. | Acct. No.

..... St. | Reading A. T. | Tap No.

Date Tested

Number of Cubic Feet	Discharge G. P. M.	PRESSURE Inlet	PRESSURE Outlet	%	REMARKS

Meter Test Record Form

Storage Shelves

Then there is what we call the "bakers wagon shelf-storage," a series of shelves, grooved and slotted to hold gear trains, registers, covers, discs, and chambers. This is the finest method of storage; with this scheme many supplies can be stored in a very small space.

The next section is made up of three drawers for miscellaneous storage, equipment, and tools.

Record File Handy in Shop

At the end of a bench is sufficient space for a steel desk which contains a card file of all of the meters. These record cards show a complete meter history as to where and when installed, when the meter has been taken out to be tested; also the results of the tests, with a list of all material used in making changes or repairs. This desk also serves as a place to do the necessary book work by the meter-man and a place to keep his test books, etc.

Along the other side of the room are three sets of steel shelving which is ample storage for all active meters. That is, those brought back from summer service for winter storage, and from houses where service has been discontinued for an indefinite period. There are seven shelves, each supplying space to store 250 meters.

We read all meters by districts, as we have the town divided up into A, B and C sections, and so we have assigned Section 1 for meters in District A, and Sections 2 and 3 for Districts B and C.

All inactive meters are stored away in another room, which leaves this room entirely for active material, which plan makes for better "housekeeping."

DANVERS WATER WORKS

Name .....

Address .....

Size & Make .....

Number .....

Reading .....

Date .....

Remarks .....

.....

By .....

DANVERS WATER WORKS

Name .....

Address .....

Size & Make .....

Number .....

Reading .....

Date .....

Remarks .....

.....

By .....

Meter Record Card and Stub

At the end of the storage racks is a cabinet of ten drawers, all divided up into small compartments, which holds the small parts of the registers, gear trains, discs, etc. Over the bench are three sets of very small drawers, which hold several sizes of change gears and some parts of the discs and gear trains.

This description will give a pretty good idea of what a well fitted meter testing room should have, to test and maintain 3,000 meters. The only difference between what we have and a city having, say, 7,500 meters would be: first, a testing machine of greater capacity; second, a little larger bench; and third, additional storage facilities.

Design to Save Steps and Loss Motion

Make your room cozy, don't make it too barny. Arrange the testing machine, washing basin, and repair bench close together. It saves time and steps, steps—and this is very important. In some meter rooms the meter man spends far too much of his time walking back and forth and back and forth from one operation to another.

Our meter room is the result of my observations in a great many other water plants and from the many helpful suggestions received from superintendents and meter-men who actually do the testing. All water works men are invited to visit this meter room, for it may offer some thought or suggestions toward even a better set-up than at Danvers.

There seems to be no fixed standard procedure in testing, and, furthermore, no one in authority (like a sealer of weights and measures) ever checks up to see whether or not the meter has been properly and thoroughly tested to the mutual interests of the customer and the utility.

Why Not "Standards of Testing Procedure"?

The thought has occurred to this writer —why not have the A.W.W.A. Meter Specification Committee also develop "Standards of Meter Testing Practice," to serve as a pattern in equipping meter-test shops of various sizes, and a guide in the proper and most dependable procedures and operations in actual routine testing practice? To the writer, at the time of designing and equipping the Danvers meter-room, and to many others contemplating new meter shops or revamping existing ones, such a guide would prove of high value and usefulness. It will also go far toward bringing standardization and better practices into the important field of metering, where there appears to be room for much improvement and a real need for standardization.

Two More Views

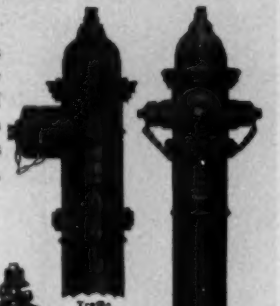
Looking "aft" down the bench. A close look will reveal the highly useful air hose at the central working space.

Another look at the "wet-end" of the room. Wash-sink, with storage beneath, and the Ford testing machine.

M & H VALVE AND FITTINGS COMPANY

ANNISTON, ALABAMA

The letters M & H are the sign of quality on Valves, Hydrants and Pipe Line accessories. High quality materials, simplicity of design and expert workmanship have established for M & H enviable reputation for dependable service in the water works and sewage fields and for industrial uses. M & H products are modern in design, with many exclusive M & H features.



M & H VALVES AND FIRE HYDRANTS

M & H A.W.W.A. Gate Valves are furnished double disc, parallel seat, iron body, bronze mounted, non-rising stem, or outside screw and yoke. Available spur or bevel geared and with enclosed grease case, also hydraulically or electrically operated. Sizes 2" to 30". Low Pressure Valves and Square Bottom Valves are an established part of the M & H line.

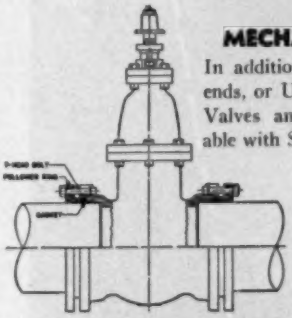
M & H Compression Type Hydrants conform to latest specifications of the American Water Works Association. They are available either in standard or traffic models. Hydrants with 5¼" and 6¼" valve opening are listed and approved by Underwriters Laboratories of Chicago and Associated Factory Mutuals of Boston. Hydrants with 4¼" and 4½" valve opening are A.W.W.A. approved only.

Outstanding features include dry top, easy to lubricate, revolving head. Can be lengthened and working parts completely removed without digging up hydrant.

FILTER PLANTS & SEWAGE PLANTS

Hydraulically and electrically operated M & H Valves are used in sewage treatment plants, water works, filter plants, etc., to save time and labor since these valves can be operated by remote control for quick, easy closing or opening. They are also used as emergency valves to admit higher water pressures into the mains in case of fire. Sizes 2" to 30" A.W.W.A.

M & H Flap Valves and Shear Gates are iron body, bronze mounted, used in Filtration and Sewage Disposal Plants.



MECHANICAL JOINTS

In addition to hub ends, flanged ends, or Universal joints, M & H Valves and Hydrants are available with Standardized Mechanical Joint ends for use with standardized mechanical joint cast iron pipe as adopted by the Cast Iron Pipe Industry.

FIRE PROTECTION

M & H makes a complete line of valves, hydrants, indicator posts and underground pipe fittings for fire protection water systems. All of these M & H products are approved and listed by the National Board of Fire Underwriters of Chicago and by the Associated Factory Mutuals of Boston. All castings therefore are marked "UA—FM."

M & H PRODUCTS INCLUDE:

WALL CASTINGS	SPECIAL CASTINGS	TAPPING SLEEVES AND VALVES
CHECK VALVES	FLOOR STANDS	SPRING LEVER CHECK VALVES
EXTENSION STEMS	SHEAR GATES	MUD VALVES
FLAP VALVES	SLUDGE SHOES	FLANGE AND FLARE FITTINGS
FLANGED FITTINGS	O & S FITTINGS	CUTTING-IN TEES

ACIPCO

When you buy anything, you want the best quality you can get for your money. Our trade-mark on our products gives you this assurance. The trade-mark "ACIPCO" means the materials used in manufacturing our pipe are warranted to be first class and the workmanship is guaranteed to be of finest quality.

As America's largest individual cast iron pipe foundry, ACIPCO manufactures a complete line of cast iron pipe and fittings in diameters from 3" to 48", inclusive. The pipe which is made by the Mono-Cast centrifugal process is equipped with any of a wide variety of joints including Bell and Spigot, Doublex Simplex, Molox Ball and Socket, Roll-On-Rubber Ring, Screw-Gland and Flanged. All ACIPCO pipe is manufactured under close control to meet nationally recognized standard specifications.

Being cast iron, ACIPCO pipe enjoys an enviable reputation. Cast iron pipe has had over three hundred years of service abroad and more than one hundred years of service in the United States. It serves equally well beneath crowded city streets or in cross country installations.

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VALVE AND HYDRANT MAINTENANCE*

By HOWARD W. NIEMEYER

Supt. of Distr., Indianapolis Water Co., Indianapolis, Ind.

CONSUMER dependence on an uninterrupted public water supply has grown almost beyond belief within the past two decades or so. Mechanical refrigeration, air conditioning, water-cooled industrial machines and other modern uses are creating such a continuity of essential demands that there is no longer a satisfactory or convenient time to shut off water service. Simultaneously, public tolerance for interruptions even in normal domestic service seems to be disappearing. This demand for a higher standard of service will force the plant operator to give more and more consideration to valves and hydrants.

Systems with inadequate valving will require the installation of additional main-line valves to minimize the areas of service interruptions which cannot be avoided. Unvalved hydrant leads, particularly in critical areas, will need valving to eliminate main shutouts during repairs. More thought will have to be given to the selection of the type of valves to be installed in large feeder mains for operation against unbalanced pressure. Particular attention must be paid to the design and structure of valves, to insure their endurance for the life of the pipeline so that they themselves will not be a cause for service interruptions to effect their repair or replacement. A preventive maintenance program for valves and hydrants, which has always been good operating practice, has become a must in perpetuating their readiness to serve.

It is unfortunate that valves and hydrants are not self-sustaining. The infrequency of their use may lead to the false assumption that they are not subject to wear and therefore remain in good operating condition without attention. The converse is more likely to be true, however, in that lack of use may be more detrimental than frequent operation. There are numerous forces at work which can cripple or destroy their usefulness for the purpose for which they were installed.

Corrosion

Probably the most serious distribution system problem today is corrosion. One phase of this problem has resulted from the promiscuous use of unprotected dissimilar metals in the structure of system components. Cast iron and bronze have long been the common metals used for water works materials. Separately they have an excellent record of endurance, but, suspended together in a solution, they produce galvanic corrosion. The rate and effect of this corrosive action in valves and hydrants will depend on their design and on the mineral content of the water, but it is always detrimental. Until such time as this problem is fully recognized and solved in either metal or structure design, the plant operator's difficulties will continue. It may be noted that galvanizing of the iron parts has been tried with some degree of success, but experience with this type of protection is insufficient to determine its long-range effectiveness.

In any corrosive action, there is a loss of metal, which results in a weakening of the affected part. If it is a working part subject to operating strain, progressive corrosion can eventually lead to failure. Equally as serious in valves are the products of corrosion, which form on the surfaces of moving parts and reduce or eliminate entirely the essential clearances needed for their freedom of movement. Periodic operation of valves will break off the corrosion deposit and help maintain the required clearances. Valves that have not been used for many years may be found to be entirely inoperative, because corrosion has swelled and then welded the moving parts into an unmovable, oversize mass.

Corrosion in hydrants does not exist in the same degree as in valves since the moving parts normally remain relatively dry. This situation changes, however, if the hydrants are set in an area of ground water that is sufficiently high to submerge their lower operating parts. Then corrosion can make their condition deteriorate enough to cause failure.

The stuffing-box gland of valves and hydrants is another source of difficulties presenting maintenance requirements. Corrosion that is primarily galvanic also takes place at this point and fills the clearance space about the stem with deposits. The most serious effect of this action is the increase in torque required to operate the affected valve and hydrant. Periodic operation will tend to work the denosit out of the gland and keep the operating stem moving freely, while neglect will allow the deposit to grow and harden until the stem becomes tightly wedged in the gland.

Of course, periodic operation of the valves and hydrants will cause a disturbance in the packing material in the stuffing gland. If this material has lost its resiliency, the gland will start leaking. This condition is not a problem in hydrants since they can readily be repacked, and it does not become a problem in valves until they leak continuously with the stem collar seated against its socket. A valve that leaks only during its operating cycle is a fault which is not serious enough to warrant the expense of the pavement cutting necessary to install new packing. Packing failures are sufficiently common, however, to require careful selection of the material to be used. The most satisfactory packing will be one that is noncorrosive, has permanent lubricating qualities, will not dry out and will seal with a minimum clamping pressure. Experience indicates that only a few types of packing will meet all of these requirements.

Street Improvement

High on the list of causes of valve and hydrant difficulties is street improvement and maintenance work. Experience would indicate that street contractors and city maintenance crews do not share the plant operator's view of the importance of keeping the utility's appurtenances in readiness for emergencies. Apparently they consider valve boxes and vaults as objects to be destroyed or buried, and fire hydrants are merely bumping blocks for bulldozers and road graders. Rigid inspection of all known street improvement jobs is necessary to see that all valve boxes and vaults are in position and properly graded. It is helpful to make a survey in advance of the construction work and to drive reference stakes along property lines to mark the location of all valves. It is also good practice to install new packing in the valves and to perform any other needed maintenance before a new pavement surface is put in place. If additional valving is advisable in the area of the street improvement, it can be installed without paying the high cost of pavement cutting and repairing. In addition, hydrants may have to be relocated to suit changes in curbings.

Street improvement or major resurfacing projects can be watched to guard against damage to the distribution system parts, as the utility will have advance notice of such work. It is the street maintenance crews, who cannot be followed, that are responsible for the large number of valve boxes covered or destroyed each year. Asphalt patching crews can be depended upon to cover with bituminous material any valve box in the area of a street repair. Road graders used on the unimproved streets will regularly break or tear up valve boxes without such damage being reported to the utility. The time lost by the utility in emergencies because of these artificially created difficulties can be quite serious.

Homeowners, in regrading their lawns, may either extend a terrace or cut the grade around a hydrant located at the property line. In the former situation, the hydrant nozzles may be so close to the ground as to interfere with the connection of a fire hose. In the latter, the hydrant is left standing high in the air, an unsightly object, and frost may penetrate to the base because of insufficient earth cover. Owners also have built fencing so close to a hydrant that it prevents the spinning of the operating wrench. These home projects which create hydrant hazards are seldom reported.

Effects of Traffic

Traffic can result in unfavorable conditions. Valve boxes located in an unstable road bed may be shifted by traffic loads so that the operating key cannot be engaged with the valve key nut. Boxes may be tilted so that a protruding edge becomes a hazard to pedestrian traffic. Vaults may become weakened, leading to the danger of a cave-in under traffic.

Hydrants are also traffic casualties and can be damaged in unreported collisions so as to render them useless to the fire department. They may be knocked out of alignment, the nozzle treads injured, the nozzles knocked loose in their sockets, or the base assembly damaged by an impact. In one hydrant, a test showed the barrel to have been broken in two, yet the hydrant appeared to be in good condition. If such damage is not reported to the utility, it must be found by regular inspection, or the faults may continue to exist until a hydrant is needed for fire fighting.

In replacing collision-broken hydrants, it is well to inspect their setting to determine if they need be relocated to a less vulnerable position. Hydrants should be

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set a safe distance from a curb and as far from street intersections as possible. The breakoff type of hydrant has many advantages and merits careful consideration. A collision with this type does not result in an emergency, and, since the broken section is readily discernible, a prompt report will probably be made to the utility. Furthermore, repairs can be made without shutting off the main.

Freezing Climates

In freezing climates, where hydrants must drain for wintertime service, tree roots are always a source of difficulty. The importance of keeping the drain ports open is obvious. It is a good practice during the winter to check all hydrants as soon as possible after their use by the fire department. Nondraining hydrants should immediately be drained with a handpump to keep them in readiness for additional service until a maintenance crew can open the drain ports. Clogged drains can often be opened with compressed air to avoid an excavation job. The installation of a piece of copper wire or tubing in the hydrant drainage bed to stop root growth has been suggested.

Much damage can result to valves and hydrants through their use by inexperienced or unauthorized persons. Valves may be left partially or completely closed. Hydrants may be damaged or left partly open. Hydrant caps may be left loose or not replaced at all. To safeguard against these irregularities, all valve and hydrant operations should be strictly confined to the distribution system maintenance division, and operation by any other plant personnel or by outsiders such as street contractors, construction workers or contractor main-laying personnel should be prohibited. Temporary hydrant connections occasionally required by outsiders should be furnished by the utility with the installation of a hand wheel valve on a hydrant nozzle, leaving the hydrant open for the duration of the use. Such hydrant operation should be reported to the fire department. This policy assures that full knowledge of all valve changes will be available to the division responsible for distribution system emergencies, and it limits all operations to experienced personnel.

An exception to the above policy will, of course, have to be made for the fire department and city street-flushing and sewer-cleaning crews. There should be a special effort to give these groups instruction in the proper use of hydrants. A sectional hydrant can be furnished by the utility for training purposes.

All instructions should particularly emphasize the importance of replacing all nozzle caps as tightly as possible. Failure to do so is an invitation to trouble from the younger generation.

Testing Programs

Ample illustrations have been given to prove the need for periodic inspection of valves and hydrants if they are to be maintained in a ready-to-serve condition. Should the many faults that can and do develop be left to accumulate over a period of years, the plant operator might find himself in a desperate situation when a real emergency arose. The frequency of periodic inspections varies, but generally a yearly interval is adopted. The hydrant testing program is preferably conducted during the fall since most faults develop in the spring and summer. Autumn testing also allows conditioning of the hydrants ahead of winter service requirements. There is no particular seasonal advantage for valve testing.

Complete and accurate maps and records of the distribution system are essential in establishing the testing programs. Simply stated, a valve cannot be tested if there is no record of its installation. Numerous water works publications have described map and record systems that are considered good practice. It is suggested that, in addition to the standard system records, it is worth while to have a permanent test report card for each valve and hydrant. Such a card carries a complete description of all physical data regarding each installation—make, size, type, location, measurements from reference points, date of installation, identification number and a test route number. In addition, the valve test card should show the type of setting (box or vault), the number of closing turns and the direction of turning, if any plant operator is so unfortunate as to have mixed directional valves in his system. A 5 × 8-in. card will allow enough horizontal lines for at least 30 test reports, using both sides. Vertical columns with headings of items to be reported will permit the testing personnel to use check marks, requiring only a minimum of writing. The cards should be filed in the office by route number and should be taken out in the field only in quantities sufficient for a day's work.

The use of test report cards has a number of advantages: Once an efficient testing route has been developed, it can be followed for all subsequent tests. There is less likelihood that any valves or hydrants will be missed. The testers carry with them, in convenient reference form, complete information regarding each installation, and also have the benefit of all past testing history, so that they are aware of any abnormal condition that may exist. A considerable saving in paper work results.

As previously mentioned, the existence of both left- and right-hand valves in a system is an unfortunate circumstance, particularly if there is an absence of maps and records which accurately specify the operating direction of each valve. It would appear that valve operations are confusing enough to warrant the conversion of all valve to a single operating direction.

The testing of valves and hydrants requires the operation of the devices through their entire cycle, as partial operation is insufficient to establish their true condition. The purpose of the inspection is to determine readiness to serve, which can be judged only from a complete test.

Minor Maintenance

During the test deficiencies other than faulty operation should be detected almost automatically, and certain items of minor maintenance should be performed as part of the testing program.

The hydrant work should include lubrication of the operating nut, tightening or replacement of the stuffing-gland packing as needed, greasing of the nozzle cap threads and calking of loose nozzles. Obstructions to the visibility of the hydrant and poor condition of paint should be noted in the test report. It is also suggested that, since travel time is a considerable item in the inspection cost, other types of surveys can be incorporated in the program at slight added expense. Little time is required for the testing crew to listen in on each hydrant with some type of mechanical or electronic leak detector. A pressure survey of the entire distribution system can be readily obtained by having the crew install a nozzle cap equipped with a pressure gage. Some utilities take a pitot measurement of each hydrant's delivery rate, while others have the testing crew flush all hydrant leads and some dead-end mains. Three men can test about 120 hydrants in an eight-hour day. The addition of a leak and pressure survey to the program will only reduce the number of hydrants tested in the same length of time to 100.

The maintenance work which can be incorporated in a valve testing program is rather limited because the valves are inaccessible unless installed in vaults. Stuffing-box packing can be replaced or tightened in vaulted valves, if required. Likewise, geared valves can be cleaned and lubricated as needed. Maintenance of buried valves during testing is limited to finding and adjusting the height of valve boxes in dirt streets and cleaning boxes of obstructions. Hard-turning valves and those which will close only partially should be worked until they operate freely. It has been found helpful in working a hydrant branch valve to open the hydrant sufficiently to secure a scouring velocity through the valve. Sometimes a scouring velocity can be obtained through main-line valves by closing off a section of main in back of the valve and opening a hydrant leading off this section. Even valves with kinks in the stem which allowed only partial closure have been worked until the valve operated freely through the kinked section. The operation of these faulty valves is considered an important part of the testing program. Each valve which can be conditioned in this manner eliminates a main shutoff, a street excavation and the need for opening the valve in order to make repairs.

Power Operation

In the author's opinion an adequate and satisfactory job of valve testing cannot be done manually. Even if all the valves were in perfect condition, the physical requirements for testing a system of any size would place a considerable strain on the personnel. It is not possible to operate faulty valves manually in the way previously discussed. Power operating equipment is available for such work and should have preference.

One method of power operation is the use of a compressor-driven air motor of low speed. This type has the advantage of reaching valves inaccessible to trucks, but there is a drawback in that the air motor must be held by the crew in opposition to the turning torque of the valve. As in manual testing, the valve turns must be counted and there is always a likelihood of error, particularly in operating large valves which require a great many turns.

Another method employs a truck-mounted operating head powered by a takeoff from the truck engine. The head can be mounted on the right-hand side so that valves near a street curb can be reached by the operator with the truck going in the direction of traffic. With the right-hand mounting, the revolution counter, which is part of the equipment, is installed on the truck instrument panel, enabling the testing personnel to synchronize the flow of power with the registered position of the valve faces. Damage to valves is avoided by the use of multiple shear pins in the driving linkage, varied in number to suit the size of valve being tested. This type of power testing has made a hard job easy and has been used

with most satisfactory results for all sizes of valves, even down to 4 in. Excellent results have been obtained with it in conditioning valves.

The valve testing truck at Indianapolis, Ind., is equipped with a phone, and the testing crew has been given the assignment of making emergency and routine main shutouts. Tighter valve closures are being obtained than with manual operation, and the maintenance crews have drier repair jobs.

There are intangible benefits to be derived from the periodic testing of valves in addition to those resulting from the location and repair of faults. The valve operating crews become thoroughly acquainted with the distribution system, its shutoff sections, the location of valves and their operating characteristics. With this experience, they can meet an emergency situation with precision, and valuable time is saved when it is needed most.

Valve and hydrant defects reported by the testing crew should be repaired as quickly as possible, the inoperative ones being given initial preference.

Hydrant painting is not connected with the testing program but is a maintenance job that should also be performed on an established schedule. The selection of the color to be used should be based entirely on visibility, particularly at night. The frequency of painting will be determined by the durability of the paint and the exposure of the hydrant to grime and dirt. Some utilities paint the hydrant bonnets and caps according to a color code which denotes the delivery capacity of each hydrant. This practice is an aid to the fire department.

The National Board of Fire Underwriters has established minimum standards for the installation of valves and hydrants needed to maintain adequate fire protection service. In order to satisfy these recommended standards and at the same time meet the high level of general service required by modern public water supply uses, valves and hydrants must be given proper consideration.

WATER PRESSURE

Feet of Head ⇄ Pressure

Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.
1	0.43	34	33.30	107	46.34	180	69.31	213	92.30	285	123.45
2	0.86	35	33.82	108	46.78	181	69.74	214	92.69	290	125.62
3	1.30	36	34.56	109	47.21	183	70.17	215	93.13	295	127.78
4	1.73	37	34.99	110	47.64	183	70.61	216	93.56	300	129.95
5	2.16	38	35.12	111	48.08	184	71.04	217	93.99	305	132.12
6	2.60	39	35.56	112	48.51	185	71.47	218	94.43	310	134.28
7	3.03	40	35.99	113	48.94	186	71.91	219	94.86	315	136.44
8	3.46	41	36.42	114	49.38	187	72.34	220	95.30	320	138.62
9	3.90	42	36.85	115	49.81	188	72.77	221	95.73	325	140.79
10	4.33	43	37.29	116	50.24	189	73.20	222	96.16	330	142.95
11	4.76	44	37.72	117	50.68	170	73.64	224	96.60	335	145.12
12	5.20	45	38.15	118	51.11	171	74.07	224	97.03	340	147.28
13	5.63	46	38.58	119	51.54	172	74.50	225	97.46	345	149.45
14	6.06	47	39.03	120	51.98	173	74.94	226	97.90	350	151.61
15	6.49	48	39.45	121	52.41	174	75.37	227	98.33	355	153.78
16	6.93	49	39.88	122	52.84	175	75.80	228	98.76	360	155.94
17	7.36	70	30.32	123	53.28	176	76.23	229	99.20	365	158.10
18	7.79	71	30.75	124	53.71	177	76.67	230	99.63	370	160.27
19	8.23	72	31.18	125	54.14	178	77.10	231	100.0	375	162.43
20	8.66	73	31.62	126	54.58	179	77.53	232	100.46	380	164.61
21	9.09	74	32.05	127	55.01	180	77.97	233	100.93	385	166.78
22	9.53	75	32.48	128	55.44	181	78.40	234	101.36	390	168.94
23	9.96	76	32.92	129	55.88	182	78.84	235	101.70	395	171 11
24	10.39	77	33.35	130	56.31	183	79.27	236	102.23	400	173.27
25	10.82	78	33.78	131	56.74	184	79.70	237	102.66	425	184.10
26	11.26	79	34.21	132	57.18	185	80.14	238	103.09	450	195.0
27	11.69	80	34.65	133	57.61	186	80.57	239	103.53	475	205.77
28	12.13	81	35.08	134	58.04	187	81.0	240	103.96	500	216.58
29	12.56	82	35.52	135	58.48	188	81.43	241	104.39	525	227.42
30	12.99	83	35.95	136	58.91	189	81.87	242	104.83	550	238.25
31	13.43	84	36.39	137	59.34	190	82.30	243	105.26	575	249.09
32	13.86	85	36.82	138	59.77	191	82.73	244	105.69	600	259.90
33	14.29	86	37.25	139	60.21	192	83.17	245	106.13	625	270.73
34	14.73	87	37.68	140	60.64	193	83.60	246	106.56	650	281.56
35	15.16	88	38.12	141	61.07	194	84.03	247	106.99	675	292.40
36	15.59	89	38.55	142	61.51	195	84.47	248	107.43	700	303.23
37	16.03	90	39.08	143	61.94	196	84.90	249	107.86	725	314.05
38	16.46	91	39.42	144	62.37	197	85.33	250	108.29	750	324.88
39	16.89	92	39.85	145	62.81	198	85.76	251	108.73	775	335.72
40	17.33	93	40.28	146	63.24	199	86.20	252	109.16	800	346.54
41	17.76	94	40.72	147	63.67	200	86.63	253	109.59	825	357.37
42	18.19	95	41.15	148	64.10	201	87.07	254	110.03	850	368.20
43	18.62	96	41.58	149	64.54	202	87.50	255	110.46	875	379.03
44	19.06	97	42.01	150	64.97	203	87.93	256	110.89	900	389.86
45	19.49	98	42.45	151	65.40	204	88.36	257	111.32	925	400.70
46	19.92	99	42.88	152	65.84	205	88.80	258	111.76	950	411.54
47	20.35	100	43.31	153	66.27	206	89.23	259	112.19	975	422.38
48	20.79	101	43.75	154	66.70	207	89.66	260	112.62	1000	433.18
49	21.22	102	44.18	155	67 14	208	90.10	261	113.06	1500	649.7
50	21.65	103	44.61	156	67.57	209	90.53	262	113 49	2000	866.3
51	22.09	104	45.05	157	68 0	210	90 96	270	116.96	3000	1299.5
52	22.52	105	45.48	158	68.43	211	91.39	275	119.12		
53	22.96	106	45.91	159	68 87	212	91.83	280	121.29		

Based on a density of 62.355 pounds per cu. ft. for water at 62°F.

THEORETICAL HORSEPOWER

$$\text{Water Horsepower} = \frac{\text{G. P. M.} \times \text{Head in Feet}}{3960}$$

Gallons per minute	HEAD IN FEET												
Ft.	10	15	20	25	30	35	40	45	50	60	75	90	100
10	.03	.04	.05	.06	.08	.09	.10	.11	.13	.15	.19	.23	.25
15	.04	.06	.08	.09	.11	.13	.15	.17	.19	.23	.28	.34	.38
20	.05	.08	.10	.13	.15	.18	.20	.23	.25	.30	.38	.45	.50
25	.06	.10	.13	.16	.19	.22	.25	.28	.32	.38	.47	.57	.63
30	.08	.11	.15	.19	.23	.26	.30	.34	.38	.45	.57	.68	.75
35	.09	.13	.18	.22	.26	.31	.35	.40	.44	.53	.66	.80	.88
40	.10	.15	.20	.25	.30	.35	.40	.45	.50	.61	.76	.91	1.01
45	.11	.17	.23	.28	.34	.40	.45	.51	.57	.68	.85	1.02	1.14
50	.13	.18	.25	.32	.38	.44	.50	.57	.63	.76	.95	1.14	1.26
60	.15	.23	.30	.38	.46	.53	.61	.68	.76	.91	1.14	1.36	1.52
75	.19	.28	.38	.47	.57	.66	.76	.85	.95	1.14	1.42	1.70	1.90
90	.23	.34	.45	.57	.68	.80	.91	1.02	1.14	1.36	1.70	2.04	2.27
100	.25	.38	.50	.63	.76	.89	1.01	1.14	1.26	1.51	1.89	2.27	2.52
125	.32	.47	.63	.79	.97	1.10	1.26	1.42	1.58	1.89	1.37	2.84	3.16
150	.38	.57	.76	.95	1 14	1.32	1.52	1.70	1.89	2.27	2.84	3.41	3.79
175	.44	.66	.88	1.10	1.32	1.54	1.76	1.98	2.21	2.65	3.31	3.98	4.42
200	.50	.76	1.01	1.26	1.51	1.77	2.02	2.27	2.52	3.03	3.79	4.54	5.05
250	.63	.95	1.26	1.58	1.89	2.20	2.52	2.84	3.16	3.79	4.73	5.68	6.31
300	.76	1.14	1.51	1.90	2.27	2.65	3.03	3.41	3.79	4.54	5.68	6.82	7.58
350	.88	1.33	1.77	2.21	2.65	3.09	3.54	3.98	4.42	5.30	6.62	7.95	8.84
400	1.01	1.52	2.02	2.53	3.03	3.53	4.04	4.55	5.05	6.06	7.57	9 09	10.10
500	1.26	1.90	2.52	3.16	3 79	4.42	5.05	5.68	6 31	7 58	9.47	11.36	12.63
550	1.39	2.08	2.78	3.47	4.17	4.86	5.56	6.26	6.94	8.33	10.42	12.50	13.89
600	1.52	2.28	3.03	3.79	4.55	5.30	6 06	6.82	7.58	9.09	11.36	13.64	15.15
650	1.64	2.47	3.29	4.10	4.93	5.75	6.56	7 39	8.21	9.85	12.31	14.77	16.41
700	1.77	2.66	3.54	4.42	5.30	6.19	7.07	7.96	8.84	10 60	13.26	15.91	17.68
750	1.89	2.85	3.79	4.74	5.68	6 63	7 58	8.53	9.47	11.36	14.20	17.04	18.94
800	2.02	3.04	4.04	5.05	6.06	7.07	8.08	9.10	10 10	12.12	15.15	18.18	20.20
850	2.15	3.23	4 29	5.37	6.44	7.51	8.59	9.67	10.73	12.87	16.10	19.32	21.46
900	2.27	3.41	4.54	5.68	6.82	7.95	9.09	10.24	11.36	13 63	17.04	20.45	22.73
950	2.40	3.60	4 80	6.00	7.20	8.40	9.60	10.80	11.99	14.39	17.99	21.59	23.99
1000	2.52	3.79	5.05	6 31	7.58	8.84	10 10	11.36	12.63	15 15	18.94	22.72	25.25
2000	5.05	7.57	10 10	12.63	15.15	17.67	20.20	22.72	25.25	30 30	37.87	45.45	50 50
3000	7.57	11.37	15.15	18.94	23.72	26.51	30.30	34.09	37 88	45.45	56.81	68.18	75.75
4000	10.10	15.16	20.20	25 25	30 30	35.35	40 40	45.45	50.50	60.60	75.75	90.90	101.01

NOTE:—to get the BRAKE HORSEPOWER required by the pump use the following formula:—

$$\text{Brake Horsepower} = \frac{\text{G. P. M.} \times \text{Head in Feet}}{3960 \times \text{Eff.\ of the pump}}$$

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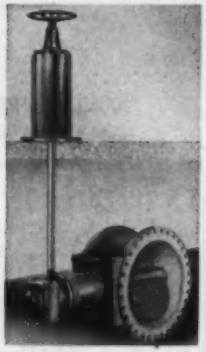

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CENTRIFUGAL PUMPS*

Notes on Selection of Pumps and Checking Pump Efficiencies

By H. E. BECKWITH
Engineer, The Pitometer Company, New York, N. Y.

TODAY the great majority of pumping stations are equipped with electrically driven centrifugal pumps, with an occasional Diesel driven or turbine driven centrifugal installation. The old slow moving reciprocating pump of yesterday could always be depended upon to take care of changing pumping loads and varying heads without any great loss in efficiency. But, this is decidedly not so with the modern centrifugal pump, designed to work under rather fixed conditions. Any appreciable variation from these conditions is accompanied by a falling off in efficiency, which may be rather marked.

Unfortunately, the non-technical water works operator who got his early practical experience with the old displacement type of pump has not always become sufficiently acquainted with the characteristics of the centrifugal pump. Only too often the only demand made on a centrifugal pump is that it pump water, and little or no attention is paid to the efficiency with which it does its work. In fact the average water works man is usually not acquainted with any simple method of determining this efficiency.

It is, therefore, the purpose of this article to point out the conditions which may be expected to cause low operating efficiency, and to outline a simple method for testing the wire-to-water efficiency which gives results as close as is necessary in practical water works operation.

Basic Principles of the Centrifugal

As a youngster I used to tie a chestnut on the end of a string and whirl it around my head until I had imparted to it the force necessary to take it flying through the air at high speed. You did it, too. The principle of building up velocity of that chestnut by whirling it about the head is the same principle which is used in the design of a centrifugal pump. The water which enters the pump through the suction inlet is seized by the rotating vanes of the impeller and spun until it is rotating at terrific velocity. Since pressure and not velocity is desired, the pump is so designed that by gradually slowing down this velocity in the casing of the pump, the energy stored up in this rapidly moving water is almost entirely changed to pressure. The speed of the chestnut rests upon two factors—the length of the string and the number of revolutions made within a specified period of time. The speed, and hence the resulting pressure, imparted to water by a centrifugal pump also rests upon the same two factors—the diameter of the impeller and the number of revolutions per minute which the impeller makes.

There are, of course, practical limits to both the speed and the diameter so that it is not always possible to secure the full desired pressure with one pump. If not, the water is passed through two or more pumps in series, and each pump raises the pressure part of the total desired amount. Sometimes these two or more pumps are built in one pump case, in which instance each pump is called a "stage." Since electrically driven centrifugal pumps operate at fixed speeds, there is always one head under which a pump will operate most efficiently. Right here it will not hurt to repeat that any material deviation from this condition will result in decreased efficiency.

Pump Performance Curves

At this point I want to introduce a typical centrifugal pump curve which we will use for illustration during this discussion. Similar curves are available from the manufacturer for all medium sized and large pumps. On small pumps it is not customary to furnish such performance curves.

It will be noted from an inspection of the specimen curve that the greatest efficiency for this particular pump (about 75 per cent) is secured when the head is about 155 ft. and the discharge rate is about 1,300 gpm. You will also note that as the head is materially increased or decreased from the optimum head there is a large change in the pumping rate and a considerable drop in efficiency. A great deal has been done in design effort to widen out the "peak" of the efficiency curve into a "plateau" so as to give high efficiencies for centrifugal pumps under a wider range of operating conditions. Considerable progress has been made in this direction.

Friction Head—Its Importance

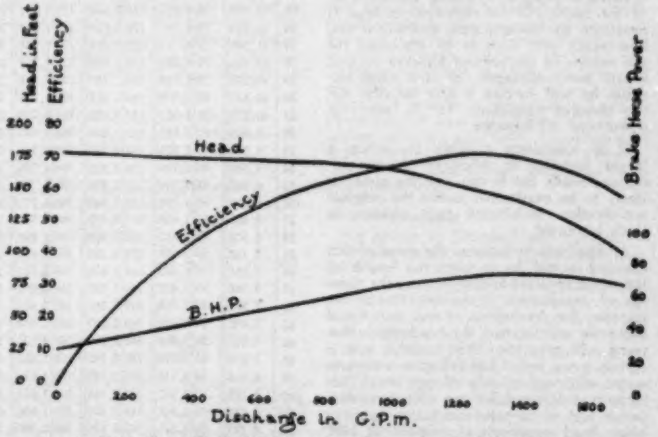
Let us see what happens when we forget to include pipe friction loss when figuring the total head against which the pump must operate. If we have figured on the pump whose curve we have, and if we are pumping through two miles of 16 in. main, the friction loss will add about 18 ft. to the pumping head—making it 173 ft. At this head (see curves) the pumping rate will drop to 1,000 gpm. and the efficiency to 70 per cent. Furthermore, the pump is operating on a very critical part of the curve where a slight increase in pumping head—caused by tuberculation in the main or by any other reason—would incur a precipitate drop in both the efficiency and the pumping rate. It also illustrates what can happen to a pump, after installation, when the pumping head has been increased above the head for which it was designed. As it is the nature of unlined iron and steel mains to tuberculate, resulting in a constantly rising friction loss, this is an important consideration.

Let us illustrate this in another way.

Selecting the Right Pump

Suppose that we are in the market for a 1,000 gpm. pump operating against a total head of 173 ft., and a pump whose curve we have been using has been submitted for consideration. I would not consider this pump a good "buy" to operate under these conditions. In the first place it will be noted that the efficiency of 70 per cent is much below the maximum efficiency of 75 per cent. But even more important, perhaps, is the fact that the pump at 173 ft. head is operating under "critical head" conditions. An increase of only about 8 ft. (less than 5 per cent) in the pumping head would bring the head to the maximum which the pump can create—in other words to the "cut off" point. This means that an increase in the head of only 8 ft. (about 3½ pounds) would decrease the pumping rate from 1,000 gpm. to zero gpm. Moreover an increase of only 3 ft. in head would cause a drop of 200 gpm. in the pumping rate. On the other hand, when we are working in the most efficient range of the pump a change of 3 ft. in the head would only cause a variation of 30 to 40 gpm. in the pumping rate; and, the efficiency is practically unaffected.

It follows, therefore, that one should buy a pump within the range where the efficiency curve is as *flat* as possible and the head curve is as *steep* as possible. In this connection a word of warning may not be amiss. By making the vertical scale of the



An Example of Typical Performance Curves for Centrifugal Pumps. Various designs show individual characteristics in respect to the curves produced.

* Excerpts from a paper presented before the Penna. Water Operators Association and an earlier article by Mr. Beckwith in previous Reference & Data Issues of this magazine.

curve less than is customary, a much flatter *appearing* efficiency curve can be secured. So in comparing the performance curves of pumps be sure that they are plotted on comparable scales. I have known curves with reduced vertical scales to be submitted where I felt sure that the scale was deliberately reduced for the purpose of deception.

Mistaken Economy

Only too often in the revamping of a plant, efforts are made to re-use as much of the old equipment as possible. It may be assumed that if the old pump will handle 1,300 gpm. against 155 ft. of head it should have less trouble pumping the same amount from the river to the settling basin against a head of only forty or fifty feet. This is so. In fact, if we will look at the curve we will find it will pump more than 1,300 gpm. at the lower head. The curve does not go out that far, but it goes far enough to show what would happen—not only to the pumping rate but to the efficiency as well. The pumping *rate goes up* but the *efficiency goes down*—yes, way down. Reducing the head has a tendency to cause a pump to run away much as an automobile would run away down hill when the going becomes easier if the throttle were not closed to compensate for the decreased demand for power. This running away of the pump sometimes overloads the motor so that it runs hot. To prevent this, operators raise the head artificially by partly closing a valve on the outlet side of the pump. This decreases the load on the motor and brings the pumping rate back to normal. But it burns up a great deal of power needlessly as the closed valve destroys part of the head generated by the pump and only part of the work actually performed is effective. I have known of installations, such as this, where the installation of a new pump saved more than enough power in one year to pay the entire cost of the new pump and motor and also completely depreciate the old unit replaced.

But it is not always necessary to buy a new pump just because the head has been reduced. If we will get back to that chestnut on the string we will find that we can reduce the speed of the chestnut by reducing the length of the string, at the same time keeping the number of revolutions constant. In the same manner, we can cut down the pressure generated by a constant speed centrifugal pump by reducing the diameter of the runner. If the reduction in head is moderate, the manufacturer can advise you how much will have to be machined off the outside of the present impeller so that it will pump efficiently, or at a slight expense he will furnish a new impeller for the changed conditions. Or he may cut down your old impeller.

It is sometimes possible to secure a larger impeller to efficiently handle increased heads, but in this case the motor is likely to be overloaded unless the original specification anticipated such change as loads increased.

Another way to increase the speed of that chestnut would be to keep the length of the string constant and to increase the number of revolutions. It follows that if we increase the revolutions of any centrifugal pump we will increase the head which that pump will generate. This explains why a certain pump tested last fall gave a wire to water efficiency of only 40 per cent. This pump was designed for use with a gasoline motor and to operate under the then existing head conditions at a speed of 1400 rpm. Eventually electric power became available and the pump was connected to an electric motor and the speed increased to 1,800 rpm. This, of course, increased the head generated by the pump itself, and the efficiency was consequently very low.

A somewhat similar condition was found several years ago when a 5 mgd. installation designed to work against a head of 100 pounds was found to have been connected in series to a 5 mgd. pump designed to pump against 50 pounds pressure. This gave an installation with a design head of 150 pounds, but the actual head was still only about 100 pounds. The *output* was thereby *increased* to approximately 6 mgd. but the *efficiency decreased* to the point where it was only slightly above 40 per cent. New and properly designed equipment brought the wire-to-water efficiency up to about 75 per cent.

It can be readily seen from the above considerations that the chances of buying a suitable pump from the "junk man" are just about nil. It might be "as good as new" for the conditions for which it was designed and yet be absoluately worthless under any other conditions. In fact, it would probably be a most expensive liability. Yet pumps have been bought from the equivalent of "junk men", but most frequently have been "salvaged" by the original purchaser for other duty than originally purchased for.

So far, we have been discussing equipment which has been working under conditions which made it impossible to give a creditable showing. A mere inspection of the conditions and a knowledge of the design limitations would make it evident that satisfactory performance under these conditions could not be secured. However, there are occasions where, after installation, things happen to properly selected pumps which will cut the efficiency of the equipment. There was, for instance, the time when we found a water snake wrapped

Table I—Gallons of Water Delivered per Kilowatt Hour Against Various Heads on Theoretical Assumption That Pump and Motor Are 100 Per Cent Efficient

H = head in feet. G = gallons per kilowatt hour

H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G
1	318,200	51	6,240	101	3,151	151	2,108	201	1,583	251	1,268	301	1,058	351	907	401	794	451	706
2	159,100	52	6,120	102	3,120	152	2,094	202	1,575	252	1,263	302	1,054	352	904	402	792	452	704
3	106,100	53	6,005	103	3,090	153	2,080	203	1,567	253	1,258	303	1,051	353	902	403	790	453	703
4	79,560	54	5,894	104	3,060	154	2,007	204	1,560	254	1,253	304	1,047	354	899	404	788	454	701
5	63,650	55	5,786	105	3,031	155	2,053	205	1,552	255	1,248	305	1,044	355	897	405	786	455	700
6	53,040	56	5,683	106	3,002	156	2,040	206	1,545	256	1,243	306	1,040	356	894	406	784	456	698
7	45,460	57	5,583	107	2,974	157	2,027	207	1,537	257	1,239	307	1,037	357	892	407	782	457	697
8	39,780	58	5,487	108	2,947	158	2,014	208	1,530	258	1,234	308	1,033	358	889	408	780	458	695
9	35,360	59	5,394	109	2,920	159	2,002	209	1,523	259	1,229	309	1,030	359	887	409	778	459	694
10	31,830	60	5,304	110	2,893	160	1,989	210	1,516	260	1,224	310	1,027	360	884	410	776	460	692
11	28,930	61	5,217	111	2,867	161	1,977	211	1,508	261	1,220	311	1,024	361	882	411	775	461	691
12	26,520	62	5,133	112	2,842	162	1,965	212	1,501	262	1,215	312	1,020	362	879	412	773	462	689
13	24,480	63	5,051	113	2,816	163	1,952	213	1,494	263	1,211	313	1,017	363	877	413	771	463	687
14	22,730	64	4,972	114	2,794	164	1,940	214	1,487	264	1,206	314	1,014	364	875	414	769	464	686
15	21,220	65	4,896	115	2,766	165	1,929	215	1,480	265	1,202	315	1,011	365	873	415	767	465	685
16	19,890	66	4,822	116	2,744	166	1,917	216	1,474	266	1,197	316	1,007	366	870	416	765	466	683
17	18,720	67	4,750	117	2,720	167	1,906	217	1,467	267	1,193	317	1,004	367	868	417	763	467	682
18	17,680	68	4,680	118	2,697	168	1,894	218	1,460	268	1,188	318	1,001	368	865	418	761	468	680
19	16,750	69	4,611	119	2,674	169	1,883	219	1,453	269	1,184	319	998	369	863	419	760	469	679
20	15,910	70	4,547	120	2,652	170	1,872	220	1,447	270	1,179	320	995	370	860	420	758	470	677
21	15,150	71	4,482	121	2,630	171	1,861	221	1,440	271	1,175	321	992	371	858	421	756	471	676
22	14,470	72	4,420	122	2,609	172	1,851	222	1,434	272	1,170	322	989	372	856	422	754	472	675
23	13,830	73	4,360	123	2,588	173	1,840	223	1,427	273	1,168	323	986	373	854	423	753	473	674
24	13,260	74	4,301	124	2,567	174	1,829	224	1,421	274	1,162	324	982	374	851	424	751	474	673
25	12,730	75	4,243	125	2,546	175	1,819	225	1,414	275	1,158	325	979	375	849	425	749	475	671
26	12,240	76	4,188	126	2,526	176	1,809	226	1,408	276	1,154	326	976	376	847	426	747	476	669
27	11,790	77	4,133	127	2,506	177	1,798	227	1,402	277	1,150	327	973	377	845	427	746	477	668
28	11,370	78	4,080	128	2,486	178	1,788	228	1,396	278	1,146	328	970	378	842	428	744	478	666
29	10,970	79	4,028	129	2,467	179	1,778	229	1,390	279	1,142	329	968	379	840	429	742	479	665
30	10,610	80	3,978	130	2,448	180	1,768	230	1,384	280	1,137	330	965	380	838	430	740	480	663
31	10,270	81	3,929	131	2,429	181	1,758	231	1,378	281	1,133	331	962	381	836	431	739	481	662
32	9,945	82	3,882	132	2,411	182	1,749	232	1,372	282	1,129	332	959	382	833	432	737	482	660
33	9,644	83	3,834	133	2,393	183	1,739	233	1,366	283	1,125	333	956	383	831	433	736	483	659
34	9,360	84	3,789	134	2,375	184	1,729	234	1,360	284	1,121	334	953	384	829	434	734	484	658
35	9,093	85	3,744	135	2,358	185	1,720	235	1,354	285	1,117	335	950	385	827	435	732	485	657
36	8,840	86	3,701	136	2,340	186	1,711	236	1,349	286	1,113	336	947	386	825	436	730	486	655
37	8,601	87	3,658	137	2,323	187	1,702	237	1,343	287	1,109	337	945	387	823	437	729	487	654
38	8,375	88	3,617	138	2,306	188	1,693	238	1,337	288	1,105	338	942	388	820	438	727	488	652
39	8,160	89	3,576	139	2,292	189	1,684	239	1,332	289	1,102	339	939	389	818	439	725	489	651
40	7,956	90	3,536	140	2,274	190	1,675	240	1,326	290	1,098	340	936	390	816	440	722	490	650
41	7,762	91	3,497	141	2,257	191	1,668	241	1,320	291	1,094	341	934	391	814	441	722	491	649
42	7,577	92	3,458	142	2,241	192	1,658	242	1,315	292	1,090	342	931	392	812	442	720	492	647
43	7,401	93	3,422	143	2,225	193	1,649	243	1,310	293	1,087	343	929	393	810	443	719	493	646
44	7,233	94	3,386	144	2,210	194	1,640	244	1,304	294	1,083	344	926	394	807	444	717	494	644
45	7,072	95	3,350	145	2,195	195	1,632	245	1,299	295	1,079	345	923	395	805	445	716	495	643
46	6,916	96	3,315	146	2,180	196	1,624	246	1,294	296	1,075	346	920	396	804	446	714	496	642
47	6,771	97	3,281	147	2,165	197	1,615	247	1,288	297	1,072	347	918	397	802	447	712	497	641
48	6,630	98	3,248	148	2,150	198	1,608	248	1,284	298	1,068	348	915	398	800	448	710	498	639
49	6,495	99	3,215	149	2,136	199	1,600	249	1,278	299	1,065	349	913	399	798	449	709	499	638
50	6,365	100	3,183	150	2,122	200	1,592	250	1,273	300	1,061	350	910	400	796	450	707	500	636

around the shaft with the result that the inlet ports were partially cut off and the suction lift increased way beyond the 15 feet maximum for best performance. In another and similar situation blocks of wood were found jammed in the ports. Then there was the time that low efficiency was caused by the blowing of the gasket of a multiple stage pump and the water was short circuiting back from a higher stage to a lower stage. One of our engineers once reported that an efficiency of 20 per cent was caused by the impeller slipping on the shaft.

Two interesting conditions have been found by the author which have no reference to the actual efficiency of the pumps but which were determined as the result of making efficiency tests. In one instance, where the meter through which power was purchased was used to measure the power input, it was found that an apparent low efficiency was caused by this meter being set 20 per cent high. In another instance, a pump was discharging into a closed distribution system. On the basis of the water *actually discharged* into the system (24-hour period) the pump had an efficiency of only 8 per cent. Had a standpipe or reservoir been floating on this system, the same amount of water could have been pumped with about one-eighth the amount of power which was actually used.

So much for the reasons why efficiency tests should be made at intervals.

A Simple Efficiency Test

The writer has worked out a simple method for making efficiency tests which he has been using with satisfactory results for some years.

At one foot of head and 100 per cent efficiency of *both pump and motor* it is theoretically possible to raise 318,200 gallons of water one foot with one kwh. To determine this theoretical value for any other head, simply divide 318,200 by the head involved. For instance,

$$\text{the value at 159 ft. would be } \frac{318{,}200}{159} = 2{,}001.2 \text{ gal.}$$

per kwh. In this connection the accompanying table may prove helpful in reducing calculations in pump testing.

To determine the *wire-to-water efficiency* of an installation it is only necessary to divide the actual pumpage per kwh by the theoretical value for the pumping head, as determined from the table. A rough check can be made by dividing the month's pumpage in gallons by the kwh consumed. This gives the gallons actually pumped per kwh.

Test Procedure

With the pump running, determine the total head in feet (including suction) against which the pump works. Divide 318,200 gallons by this total head (as above) to determine the theoretical 100 per cent pumpage per kwh. (Or take the figure from Table 1.) Next divide the actual gallons per kwh. by the theoretical gallons per kwh. to secure the wire to water efficiency.

To illustrate:

Assume a monthly pumpage of 32,640,000 gallons and a monthly power consumption of 30,200 kwh. Say the total head noted was 220 ft. Dividing 32,640,000 by 30,200 gives an actual pumpage of 1,081 gallons per kwh. Dividing 318,200 by 220 ft. gives a theoretical value of a possible 1,447 gallons per kwh at 100 per cent efficiency (see table). Then:

$$\frac{1{,}081 \text{ (observed)}}{1447 \text{ (theoretical)}} = 74.7\% \text{ overall}$$

wire to water efficiency.

A more accurate method of making the tests is to measure the power input for an hour, or some other convenient period of time. During this period carefully check the output of the pump with any suitable main line meter. Keep a close record also of the discharge pressure and of the suction. The integrations on most electric meters in pumping stations cannot be read closely enough for short tests. However, the power company will furnish the number of watts consumed for each revolution of the disk, and by counting its revolutions for ten or twenty minutes the rate of power input can be closely ascertained. Or the power company can be asked to measure the power by means of special equipment. Where more than one pump is taking power through the master meter at the same time, the latter method is the only feasible one for testing each unit separately.

Securing Total Head

The total head in feet must first be secured. If the pressure gauge reads in pounds, convert to feet by multiplying the pounds of pressure by 2.31 [feet of water head giving one pound gauge pressure]. The suction will probably be expressed in inches of mercury. Convert this to feet of water head by multiplying by 1.13. Also measure the vertical distance between the center of the pressure gauge and the point of suction measurement. The total head then becomes the sum of the following:

Discharge pressure, in feet	xxx
Suction in feet	xx
Vertical distance pressure gauge is above point of suction measurement, feet	x
Total Head in feet	xxx

Velocity head has been ignored, as it is a small factor for the relatively high heads which usually exist in water works operation.

If water is delivered to the pump under pressure, then the pump will be working against a head equal to the difference between the discharge pressure and the inlet pressure.

From the data secured during the test, determine the gallons delivered per kilowatt hour. As before, divide this by the theoretical valve for the head against which the pump was operating. This gives the overall wire-to-water efficiency of the installation.

As an example, let us assume an installation where we secured the following test data:

Power input to motor	90.0 K.W.
Rate of discharge	51,840 gal. per hr.
Delivery per KWH	576 gal.
Pressure	146 lb. = 337 ft.
Suction	15 in. = 17 ft.
Difference in gauge elevation	1 ft. = 1 ft.
Total head	355 ft.

Theoretical discharge 335 ft. head (see table) is $\left(\frac{318{,}200}{355}\right) = 897$ gal.

and

Overall efficiency (wire-to-water) is $\left(\frac{576}{897}\right) = 64\%$

If a suction gauge is not available, an approximation may be secured by measuring the vertical distance from the level of water in the clear well to the center of the pressure gauge, adding to this measured distance about two feet for loss in bends, etc.

What the Tests Reveal

Having shown the desirability of frequent tests and having presented a simple method for making them, it may now be interesting to discuss what these tests may be expected to show. In the first place, there have been great increases in the attainable efficiencies of centrifugal pumps within the past few years. Those of modern design may be expected to give up to the following overall (wire to water) efficiencies.

Capacity gpm.	Efficiencies Per cent
200	58
400	63
600	68
800	71
1000	73
1500	75
3000	80
5000	82
Over 5000	85

It will be noted that the larger the pump the higher the efficiencies.

There will be variations from these figures depending upon the head and other conditions. Such are submitted only for the purpose of giving something with which to compare the efficiencies of existing installations. This is important, because it will often be found that older equipment may have retained its original efficiency and yet be so inefficient in comparison with modern equipment, now available, that it is decidedly not economical to keep it in operation. It will be worth while to check the present efficiency of every centrifugal pump now more than ten years old, to determine how great a reduction in power consumption can be secured by replacement with more efficient modern pumps. You may be surprised.

If an old 1,000 gpm. pump, operating at an efficiency of 57 per cent is replaced with a new pump giving an overall efficiency of 73 per cent the same amount of water may be pumped with 22 per cent less power. This means that both the demand rate and the power consumption through each step of the existing rate schedule would be decreased 22 per cent. Such a reduction might prove enough to pay for the new installation in about one year's time. In order to get the gallons per kwh. to be expected at any head, for any efficiency, it is only necessary to determine theoretical gallons per kwh. for that head and then to multiply this theoretical value by the expected efficiency. If the total pumpage in gallons is then divided by this expected pumpage per kwh. the power consumption to be anticipated from the new installation will be secured. Similarly it is possible to determine the anticipated demand rate, which is often as important as is the total kwh. consumption in determining the power bill to be expected from a new installation. Sometimes it is more important.

A Worthy Example

An article by Marshall and Rawlins of Charlotte, N.C., revealed graphically how the power costs were drastically cut at the local pumping station by replacing old equipment with new. These power costs, which had been running about $16.00 per million gallons were cut to about $7.50 per million gallons. This cut was the result of two definite and distinct improvements. In the first place the pumping main was paralleled with a new line. This resulted in reducing the former friction loss materially. This single betterment cut the power cost from $16.00 to $12.00 per million. Following this, the not very old (but less efficient)

pumping units were replaced with modern efficient equipment. This investment, which might appear to the average municipal councilman a questionable expenditure, further reduced the pumping cost to $7.50 per million, representing a very notable day in and day out saving.

Measuring Output of Water

Table 1 has another use. Many plants, especially smaller ones, have no master meters. With the old displacement type pump it was possible to secure the approximate amount of water pumped by installing a pump stroke counter and multiplying the number of strokes by the discharge in gallons per stroke. If the pump were permitted to get into a state of disrepair, this measurement was apt to be in error, but if the pump were kept in good condition it was reasonably accurate. The method about to be outlined for obtaining the output of water from electrically operated centrifugal pumps has possibly a degree of accuracy comparable to the pump counter method.

From the efficiency curve furnished with the pump, determine the pump efficiency for the head under which the pump operates. The curve will show the pump efficiency only. The combined pump and motor efficiency, the so-called wire to water efficiency, will be about 90 per cent of the efficiency shown for the pump alone. From Table 1 secure the theoretical gallons per kilowatt hour for the head under which the pump is operated. Multiply this by the overall wire to water efficiency just secured. This gives the number of gallons per kilowatt hour the pump should deliver. Multiply this by the total number of kilowatt hours used over any given period of time and the result should be the number of gallons pumped over the same period. To illustrate:

Assume a pump with an efficiency of 65 per cent operating at a total head of 200 ft. Then 90 per cent of 65 would give an overall wire to water efficiency of 58.5 per cent. If the installation were 100 per cent efficient, Table 1 indicates the discharge woud be 1,592 gallons per kilowatt hour. With an overall efficiency of 58.5 per cent the discharge would be 1,592 × 58.5 per cent, or 931 gal. If the power consumption for the month be 20,000 kilowatt hours, then the total pumpage becomes 20,000 × 931 or 18,620,000 gal. for the month.

While this method of computing pumpage will not, as a rule, give results as satisfactory as those secured from a master meter, it does give a close approximation in instances where a master meter is not available.

In outlining the tests in this paper it has not been intended to supplant the more detailed methods used by professional engineers, but to make available to the average water works operator a method of checking which will give reasonably accurate results.

HOW TO PACK A STUFFING BOX

1. Remove all old packing from the stuffing box.
2. Clean box thoroughly, removing accumulations from walls.
3. Keep packing clean during application. The scoring of rods, shafts or sleeves often results from grit or foreign matter picked up by packing.
4. Determine size of packing required by checking diameter of rod or shaft and the inside diameter of the stuffing box. Rods wear and the packing has to compensate for this wear.
5. Never wind a length of packing into a stuffing box. Use ring form only.
6. Cut spiral or coil from packing over a shaft or mandrel of exactly the same size as the one on which the packing is to be used in order to get close fitting rings.
7. Obtain sharp clean cuts on soft packings that tend to squash or become ragged by simply applying a small piece of friction tape at the place where the packing is to be cut. It is advisable to remove the tape when installing the rings. String also serves well for tying the packing on each side of where the cut is to be made and may be left on the packing when installed.
8. Cut all packing ring joints to a snug fit making the rings meet with a tight butt or bevel joint.
9. Seat each packing ring carefully before placing the next one in the box. Loading a stuffing box with packing and then pulling up on the gland follower may cause excessive deformation of the first two rings, building up localized gland pressure and failure to seat the bottom rings so they can work effectively.
10. Install all packing rings so that joints are staggered and kept approximately 90 deg. apart. Spot joints in clockwise direction to facilitate locating them when removing packing.
11. Pull up the gland follower sufficiently tight, after the packing has been installed, to insure final seating of the packing. The nuts should be backed off two or three turns to relieve excessive pressure. Adjust packing to operating conditions.
12. Keep the following in mind for stuffing boxes provided with water, oil or grease lanterns: (a) Make sure that the lantern is so located in the box that as the packing is taken up, the lantern will be advanced to its proper location with respect to the opening in the box. (b) Check to see that the opening into the stuffing box is free from obstructions so that the sealing water or lubrication can flow into the lantern.
13. Allow packing to leak a small amount, if possible, when starting a newly packed pump. Take up the gland slowly as the packing seats.
14. Provide means for lubricating the rod and packing wherever possible.
15. Finally, carefully wrap all extra packings, place them back in their container as a precaution against waste and the possibility of their picking up dirt and other injurious foreign substances.

Courtesy of *Power*

HELPFUL HINTS FOR HANDLING PACKINGS

1. Use packings of correct size. Oversize packings are difficult to install and may cause excessive friction. Undersize packings may be ruined by too much takeup.
2. Where leakage cannot be permitted, provide a means of introducing a sealing or lubricating fluid such as water, oil or grease into the stuffing box.
3. When renewing packings, use all new, clean packing. Worn packings are dry, highly compressed, have high friction, may develop scoring.
4. Remember packing is relatively cheap. Labor and materials necessary to replace worn shafts, sleeves or rods are expensive and critical commodities.
5. Take up bolts evenly, moving to the bolt diametrically opposite, never to the bolt adjacent.
6. Follow up bolts the next day after installing new gaskets. For lines carrying high pressures, the gradual building up of the pressure and continuous follow-up of bolts is recommended.
7. Exercise great care when using gasketing dopes. Never use oil or grease on a rubber or rubber-compounded gasket. Graphite and glycerine or molasses compounds are not injurious to rubber. Never use dope on both sides of gasket—it may cause slippage or blowout.
8. Do not use a heavier sheet packing than is necessary. The thinner the gasketing material, the better.
9. Ring gaskets are preferable to full face gaskets where the flanges are heavy enough to prevent distortion.

Courtesy *Johns-Manville Corp.*

VALVE AND PRIMER CORPORATION

30 WEST WASHINGTON ST., CHICAGO 2, ILL.

Apco Automatic Pump Primers *Apco Automatic Air Relief Valves*
V-Apco Automatic Vacuum Primers

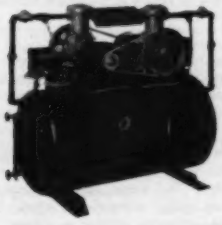
V-APCO Automatic Vacuum Primers and APCO Automatic Pump Primers

Advantages

V-APCO Automatic Vacuum Primers for centrifugal pumps offer these advantages: 1) Keep pumps always primed. 2) End loss of time due to lack of prime. 3) Operate at any vacuum under which the centrifugal pump will operate. 4) Uses no foot valve. 5) Flexible capacity; will serve additional pump installations satisfactorily. 6) Does not affect pump efficiency. 7) Improves operation of pump. 8) Simple design insures long life, freedom from trouble, highest efficiency.

How the Primer Operates

Drawing below shows the V-APCO Primer. A priming valve of the 200 series is placed on the vent of the centrifugal pump. While the vacuum pump is producing a vacuum, the valve passes all air that



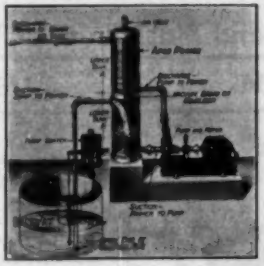
may be in the pump or suction line. When the air is withdrawn, it is followed by water which raises the valve float. That closes the outlet and prevents flooding of the vacuum pumps.

The Air Release Valve is mounted on the pump and connected to the vacuum storage tank that stores enough vacuum to act as a cushion on the vacuum pump. It provides a way to withdraw small amounts of air from the pump and suction lines from time to time. This makes frequent starting and stopping of the vacuum pump unnecessary.

A vacuum breaker on the vacuum tank unloads the vacuum pump in the unlikely event that is required. A vacuum switch with vacuum release connections is mounted on the vacuum tank and starts the vacuum pump when the vacuum drops in the storage tank and stops the pump when full vacuum has been reached. The vacuum release connection unloads the vacuum pump when it is not operating and places it in condition to start at no load.

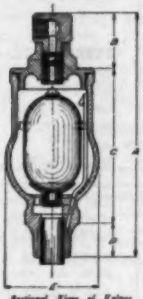
The check valve between the switch and the pump is a special noiseless one for the purpose, holding the vacuum in the storage tank when the pump is not operating.

THE APCO PRIMER

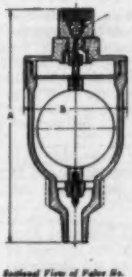


How the Apco Primer Works

This cut shows primer in service with the pump running. When the pump starts, it draws liquid from the lower chamber of the primer and discharges it through the upper chamber. The withdrawal of the liquid from the lower chamber creates a partial vacuum in this chamber which causes the liquid in the sump or well to rise in the suction pipe and flow through the primer to the pump. When the pump stops, the liquid in the upper chamber runs back through the pump into the lower chamber by gravity, thus refilling the lower chamber with liquid to prime the pump when it starts again.

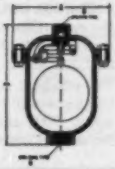


Sectional View of Valves Nos. 30-40 for Pressures Up to 60 Lbs.



Sectional View of Valve No. 30 H.D. for Pressures up to 150 Lbs.

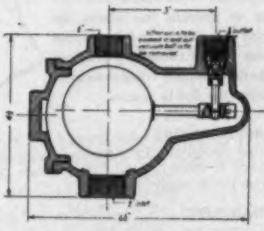
Sectional view of Valve No. 200. The valve has large venting capacities and positive opening when under vacuum.



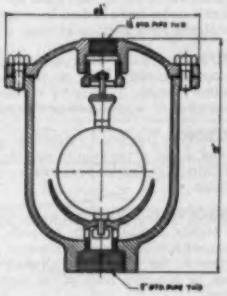
Sectional view of Valve No. 200-A.

APCO-Air Release Valves

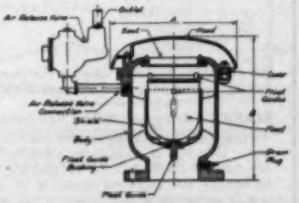
APCO Air Release Valves are made in 17 different sizes and capacities varying from the smallest with ¾" pipe connection and small venting capacity to our large 2" size with an opening of 1" diameter and vacuum and air release valve from 2" to 6". We illustrate below a very few of these types. Your venting problems can be handled by some one of our valves in the proper manner. Prices are reasonable



Sectional View of Valve No. 55.



Sectional View of Valve No. 140 for Deep Well Pumps.



Sectional View of No. 150 Series Air and Vacuum Valves.

ACTIVATED ALUM SALES CORPORATION

316 WYNDHURST AVENUE • BALTIMORE 10, MD.

Activated Alum and Blackalum for Water Treatment

ACTIVATED ALUM

Activated Alum is a non-hygroscopic mixture of filter grade alum containing very finely pulverized particles of clay in a thoroughly dispersed form. The purpose and advantage of the suspended clay is to provide the nuclei for floc formation, and to supply the weight necessary to attain better settling characteristics after the floc is formed.

APPLICATIONS—Activated Alum is generally accepted as the best coagulant for removing color and suspended matter from highly colored waters, and waters which vary through a considerable range of turbidity.

HANDLING—For convenience in handling, the Activated Alum Corporation has designed and popularized the use of 100 lb. disposable paper bags. These bags, in addition to being easier to handle than the commonly used 200 lb. burlap bags, eliminate the nuisance caused by loose fibres of burlap becoming entangled in the mechanical parts of the feeder.

STORAGE—Due to the non-hygroscopic qualities of Activated Alum, users have found that this material can be stored for relatively long periods of time without loss due to caking.

SHIPPING—Water of crystallization in Activated Alum is held to approximately 25%, as compared to an average of 45% in ordinary alum. Paying by the pound for shipping unnecessary quantities of water is thus eliminated.

FEEDING—The non-hygroscopic properties of Activated Alum are of great advantage in overcoming the difficulties caused by "arching" in the feeder hoppers under damp atmospheric conditions.

DISSOLVING—The structure of the particles of Activated Alum is highly porous. This porosity is secured in the process of manufacture and is of assistance in speeding up the dissolving action in the mixing chamber of chemical feeders. Dissolving time is actually only about half that required for crystalline alum.

CHEMICAL ANALYSIS—Activated Alum has the following typical analysis:

Alumina (Al_2O_3)	17.9%
Insolubles	9.0%
Iron (Fe_2O_3)	0.3%
Acidity	0.0%
Basicity	0.2%

the alumina (Al_2O_3) in alum is the measure of its strength. Note this is nearly 18% in Activated Alum.

SERVICE—Activated Alum Corporation, unlike nearly all other concerns supplying alum, specializes exclusively in its production. This fact is chiefly responsible for the unique service we are able to render . . . a service by which it is often possible to furnish the required quantity of Activated Alum to water works operators within hours of the receipt of emergency calls.

DUSTLESS BLACKALUM

Blackalum consists of the standard Activated Alum mixture with the addition of not less than 4% of activated carbon. This mixture is moistened to produce a congealed material, and then reground to normal alum requirements. This results in trapping the carbon particles within the alum formation, creating a truly dustless material.

APPLICATIONS—Blackalum is recommended for all water works applications where straight activated carbon has formerly been used for the removal of tastes and odors from water supplies.

HANDLING—Because of our process of pre-moistening the Blackalum mixture prior to grinding it the dusty, dirty handling characteristics common to ordinary activated carbon preparations have been overcome.

FEEDING—The mixture of carbon with alum provides a means for getting the carbon into the water without the necessity for additional feeding equipment. The same machine can be used to feed Activated Alum under normal conditions, and Blackalum at the times when activated carbon is needed.

Water works men report finding some interesting and unexpected advantages with this means of feeding carbon. They find that the activated carbon is more effective when it is introduced in the acid phase of the alum solution and that better distribution of the carbon is obtained because the entrapped particles are thoroughly wetted at the time they are released from the alum. This is a great advantage because many plants have considerable trouble with carbon floating on top of the settling basins. Further, the activated carbon provides a stabilization action in the sludge at the bottom of the settling basin.

COST—Production of Blackalum in large volume means carload purchases at a low price, and we pass this saving onto the customer. The only additional cost over regular Activated Alum is the carload rate for the carbon included. This additional cost amounts to approximately 5%.

CHEMICAL ANALYSIS—Like Activated Alum, Blackalum has the same high alumina analysis which is modified only for the presence of activated carbon.

The standard mixture is 4% water works grade activated carbon by weight (16% by volume), the remainder being Activated Alum. This mixture is available in any percentage of carbon for special use where tastes and odors are very severe.

THE CONTROL OF CORROSION

By ROBERT SPURR WESTON
Late Consulting Engineer, Boston, Mass.

EVER since metal pipes have been used for conveying, and tanks and other structures for storing or moving water, their protection against corrosion has been an important problem.

What is corrosion? Broadly defined, it is the chemical action of certain external agencies which cause the deterioration of metal. Confining attention to iron, there are several established facts regarding it which are so well known that they need be only summarized.

When corrosion is in mind, one thinks of red or rusty water, stained porcelain fixtures, stained clothes from the laundry, and leaking services. Serious as these are, far more so are the economic losses due to the flow impeding products formed on the walls of pipes of water systems, with the consequent reduction in carrying capacity, and the scaling up and pitting of steam boilers. For example, a cast iron pipe having a life of 100 years under normal conditions may lose over half of its carrying capacity in 25 years because of increased friction and decreased area of cross-section due to tuberculation or other forms of rusting. Incrustation is, therefore, more important than loss of metal, for the metal dissolved from the pipe is but a small part of the mass of iron compounds, often containing organic and mineral matter, which accumulates on the corroded surface of the attacked metal.

Because chemically pure waters are the ones which are most frequently corrosive, the troubles due to corrosion have increased as better and better waters have been supplied. For example, a colored surface water will often deposit a protective coating of organic matter on the surfaces of pipes and retard corrosion; yet, when this same organic matter is removed by coagulation and filtration, the water becomes clear, is often not alkaline, and usually is so corrosive that corrective treatment is required.

Oxygen and Hydrogen—The Corrosion Team

The active agent in the corrosion of metals is oxygen, but this element would be almost powerless by itself were it not for the action of what are known as acid or hydrogen ions. Everyone knows that water is composed of two atoms of hydrogen (H) and one of oxygen (H_2O), but, according to the well-established electro-chemical theory, an extremely small fraction of a water is dissociated into H (hydrogen) and OH (hydroxyl). The familiar term "pH value" is used to indicate the concentration of these H ions. When the concentrations of H and OH ions are equal, a water is neutral and contains one ten-millionth (0.0000001) of a gram equivalent of both ions per liter.

The scale of pH values may be compared with the fine adjustment on an engineer's transit, or a vernier on a machinist's calipers. Some of the values are as shown in above table.

The interesting and significant part about this scale of pH values is the fact that the seemingly small change of only 1 in pH value actually represents acidity or alkalinity 10 times that of the higher or lower pH value. In other words, a solution with pH value of 4 is 100 times more acidic than a solution with a pH value of 6.

How refined is the scale of pH values may be realized from knowing that the pH of a good ground water containing 50 parts per million of carbon dioxide gas may be less than 6.0; of ordinary New England river waters, 6.2 to 7.6; of alum-treated filtered waters, 5.4 to 6.6; of a water of this region just saturated with calcium carbonate (chalk), about 8.4; and of a highly alkaline water, 11.0.

The pH value is so easy to determine that it is used for explanation by many operators, some of whom tend to place too much reliance upon it. Generally it determines the *rate* of corrosion rather than the amount. The *amount* is contingent largely upon the quantity of oxygen present. Theoretically, the acid ion (H) attacks the metallic iron; then the oxygen combines with the iron, releasing the H ion for a further attack, and the cycle moves on. Consequently, the lower the pH value the higher the acid concentration and consequent *rate* of solution.

	Concentration (Grams Equivalent Per Liter)	pH Value
Acid hydrogen (H) ions predominate in this zone above the neutral line	1.0	0
	0.01	2
	0.0001	4
	0.000001	6
NEUTRAL CONDITION	0.0000001	7
	0.000001	8
	0.00001	9
	0.0001	10
Alkaline (OH) ions predominate in this zone below the neutral line	0.001	11
	1.0	14

Signs of Corrosion

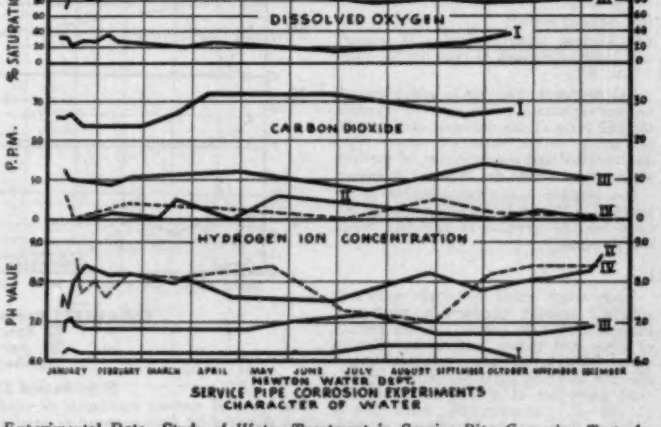
The well-known signs of corrosion are the black or green ferrous (unoxidized) rust formed next to the metal, and the reddish brown ferric (oxidized) rust at the surface, with mixtures of the two between. Some coatings are dense and retard corrosion. Some are porous and slow it down but little. Because the susceptibilities to corrosion vary greatly over the surface of the metal, the action is frequently localized in the form of tubercles, as, for example, where a protective coating inside a pipe is impenetrable except in spots. The dislodgment of rust coatings or tubercles causes the well-known "red water" troubles.

In New England, there are some well waters low in pH value, and corrosive, but which form no coatings of rust inside the pipes, and come clear at the taps. Usually these contain iron in solution and there is a streak of red rust on tub or bowl where the dissolved iron oxidizes and collects.

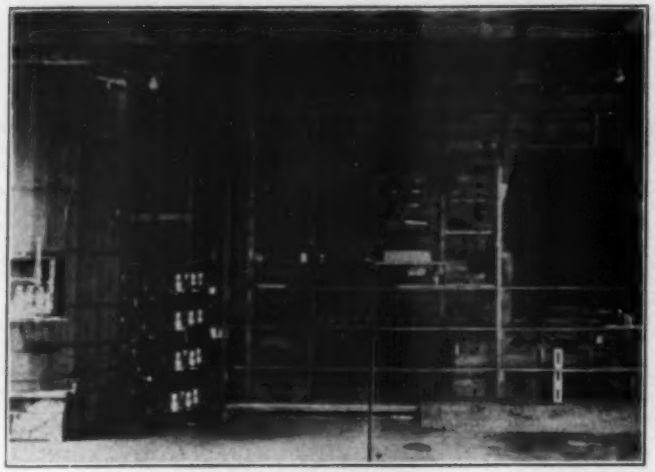
The pH value and oxygen content are not the only factors in corrosion. In natural waters the organic contents, or sulfates, carbonates, chlorides, and other salts—of calcium and magnesium particularly—reduce or modify the corrosive action of waters or affect the protective treatment required. A good critical review of modern theoretical researches with references to the works of Baylis, Langelier, Enslow, Hale and others, has been recently given by Prof. Edward W. Moore[1] of the Harvard Graduate School of Engineering.

Correction and Control

Obviously, with acid waters containing oxygen,—and most of them do,—it is well to reduce the acidity or increase the alkalinity by the addition of an alkali. For this purpose two chemicals have been used extensively, namely: carbonate of soda (soda ash), and hydrated lime—Na_2CO_3 and $Ca(OH)_2$.


I - Untreated Water
II - Raw Water Plus Soda Ash
III - Aerated Water
IV - Aerated Water Plus Soda Ash
JANUARY FEBRUARY MARCH APRIL MAY JUNE JULY AUGUST SEPTEMBER OCTOBER NOVEMBER DECEMBER
% SATURATION
DISSOLVED OXYGEN
P.P.M.
CARBON DIOXIDE
PH VALUE
HYDROGEN ION CONCENTRATION
NEWTON WATER DEPT.
SERVICE PIPE CORROSION EXPERIMENTS
CHARACTER OF WATER

Experimental Data—Study of Water Treatment in Service Pipe Corrosion Tests for Newton, Mass.



Corrosion Study Installation of Various Service Pipes for Evaluating Anti-Corrosion Treatments at Newton, Mass.

Soda-Ash

When soda ash is used, little or no insoluble coating, except iron hydroxide, is formed on the iron, and when it is added to a colored surface water, the color may be increased which is objectionable. Nevertheless it has its uses. A case at point is that of Newton, Mass.

Before 1928, the city of Newton was supplied with water from wells. Later on, conditions demanded the construction of infiltration basins which are filled from the Charles River and which are used to increase the supply from the wells. The effect was an increase in the amount of oxygen and a decrease in the amount of carbon dioxide, with resulting increase in corrosion. Brass pipe was short-lived and there were blue stains on bowls and baths where copper pipe was used. Iron, of course, was attacked also.

A series of experiments[2] were planned and carried on for about a year, using

(a) Untreated water;
(b) The regular supply treated with enough sodium carbonate to raise the pH value to 8.0;
(c) Aerated water;
(d) Aerated water treated with enough sodium carbonate to raise the pH value to 8.0.

The results showed that by adding enough sodium carbonate (soda ash) to maintain the pH value of the delivered water at 7.6 the action on the brass and copper pipes was arrested and the corrosion of the iron piping came within the limits of tolerance.

Consideration was afterward given to the addition of lime, but it was not adopted because of the increase in hardness which would result.

Lime

Lime, when added to certain waters in sufficient amount, produces a coating of calcium carbonate (chalk) on the surface of pipes and metals, and is an effective agent. However, ordinary soft local waters dissolve about 30 parts per million of calcium carbonate at a temperature of 20° C. (68° F.); consequently, when lime is added to these waters in sufficient amount, the hardness of the water is appreciably increased, sometimes to an objectionable degree. To saturate these waters with calcium carbonate, it is necessary to raise the pH value to about 8.4, with a consequent noticeable increase in hardness.

Character of Raw Water and Effects of Treatment With Soda Ash, Newton, Mass.

Results of Analysis
(Parts Per Million)

Constituent	PUMPING STATION Untreated	PUMPING STATION Treated	Supply Yard
Turbidity	0.	0.	0.
Color	2.	5.	5.
Alkalinity	26.0	74.0	72.0
Hardness	29.9	29.9	31.2
pH value	6.2	7.8	7.6
Iron	0.08	0.10	0.08
Carbon dioxide	25.0	4.0	4.1
Dissolved oxygen % saturated	33.8	.....	.....

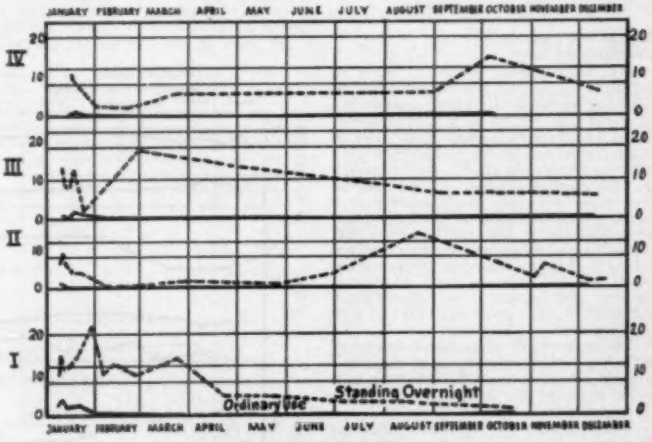
In practice, one adds enough lime to keep the pH value below 8.4 in order to avoid incrusted meter parts and piping, and above about 7.8 to keep the consumers from ringing the superintendent's telephone to complain of red water. Under these compromising conditions, there is necessarily some corrosion but usually it may be controlled by adequate flushing of the mains.

Silicate of Soda

In some cases sodium silicate (water glass) is added also, say, in small amounts with the lime, or say once a week or ten days, in larger amounts. The calcium silicate, so formed, is less soluble than the calcium carbonate and helps to maintain a protective coating on the metal. This is the practice at North Attleboro, Mass., and was the practice at Winchester, Mass., until a change was made by substituting sodium hexametaphosphate, which is more generally known as "Calgon." Concerning "Calgon" treatment more is to be said later.

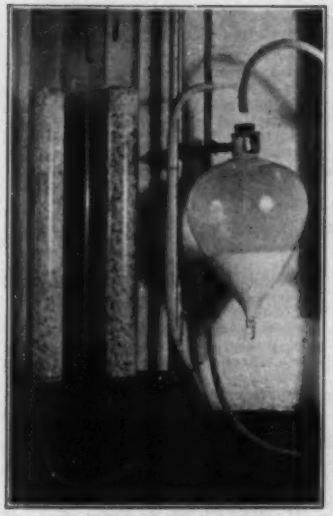
The object of the addition of lime or any other chemical is to limit the attack of the water by holding the products of corrosion at the boundary surface of the metal in the form of a thin layer. Rust alone is too porous for protection, but rust plus calcium carbonate (chalk) is generally effective. Moore[3] has referred to the work of Langelier who devised the formula for establishing the equilibrium of any water with calcium carbonate, and consequently the proper dose thereof; also that of Enslow who devised a convenient apparatus for determining continuously the widely varying degree of saturation for waters ranging in hardness or alkalinity from less than 10 to nearly 1,000 parts per million.

This apparatus saves the time of chemists in making the so-called marble test, devised by C. P. Hoover, or in arriving at the Langelier index of corrosivity, which, as stated, determines the proper dose of lime.



Experimental Data, Newton, Mass.

The effect of various treatments in subduing attack on black iron pipe reveals ppm. iron dissolved by flowing water as compared with water standing in the pipes overnight and recorded by dashed lines.



The Enslow Continuous Stability and Corrosivity Indicator

The simple and inexpensive Enslow Corrosivity Indicator is described in Reference and Data Numbers of WATER WORKS AND SEWERAGE for 1941 and 1942.

It was soon found, however, that the effects of lime treatment alone did not reach the dead ends of the system until after a considerable period, and frequently not until an undesirable accumulation of deposit had occurred near the point of application of chemical.

This is illustrated by the experience at Wakefield, R. I. where an old works has been supplying water to industrial and mercantile villages, summer and pleasure resorts over a wide area. The colored raw water is from surface sources, and for about fifty years was supplied untreated; but, while there was an accumulation of organic matter in the mains, few complaints were aroused because of corrosion.

In 1930, the works postponed the construction of a water purification plant by adding chemicals to the inlet of the lowest reservoir in the system and using it as a coagulating and clarifying basin. This was a beneficial but temporary practice, and, in 1940, after a study of the possibilities of ground water supply, pressure filters were installed and the water was treated with alum, with no provision for flocculation. The resulting acid water (usually clear and low in color) caused dislodgements and corrosion. Lime was added, sometimes in excess, and this accumulation, with the older ones, was often dislodged and caused complaint.

Experiences with "Calgon" Treatment

To delay the carbonate precipitation, and to avoid the addition of an excess of lime, the application of sodium hexametaphosphate was resorted to.

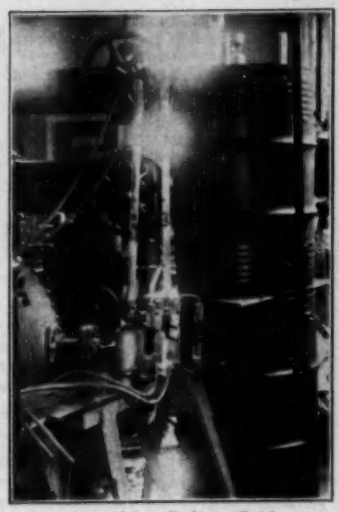
This chemical, sold under the trade name of "Calgon," was first used to delay or inhibit the after-precipitation of calcium carbonate in water softening; and, later, to cause the gradual coating of the out-lying parts of the distribution system, and to reduce accumulations near the source of supply. It was also believed that the phosphate would not only prevent excessive deposition, but, when added alone, would inhibit corrosion because of its power to form a thin protective film (said to be a molecule thick) on the surface of metal with waters having pH values on the acid side of neutrality.

The writer's first experience with this chemical was at Fairhaven, Mass.[3] Here, the raw water from wells was slightly corrosive and contained enough iron to form deposits, but too little to warrant its removal by the usual methods. Here, the metaphosphate has been employed successfully. It has controlled corrosion and has kept the iron in suspension, even at the dead ends.

Early in 1941 it was decided at Wakefield, R. I., to apply metaphosphate and to gradually reduce the dose of lime at the same time. Application of metaphosphate was begun on May 6th. Application of lime to the filter effluent was gradually reduced, and was discontinued on August 16th. Metaphosphate was applied first at the rate of 4 ppm., and later at the rate of 2 ppm. While it may be too early to give a true picture of the results, they have been satisfactory. The older chalky deposits have been removed from most of the system. "Red water" troubles have nearly ceased, and flushing of the mains is attended with less and less sediment. The present indications are that a lower dose of metaphosphate will suffice.

In the 21 months of operation, by gradually reducing the lime dosage, the pH value of the delivered water has been reduced from 8.8 to 5.2 at the filters and 6.0 at a point on a branch line four miles away.

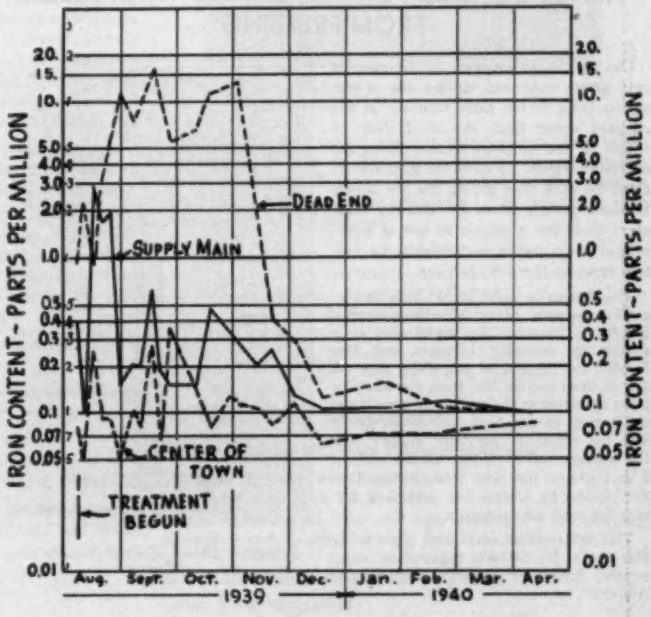
Experience with metaphosphate is still too limited, and waters vary so much in their requirements, that it is not yet possible to generalize with accuracy regarding its effects. It is found that it is an inhibitant when present at a concentration of a few parts per million, even when the pH



Experimental Installation at Fairhaven, Mass.
For studying effect of "Calgon" and other corrective treatments.

value is low. It protects iron and copper when the pH is high. On the other hand, it behaves differently when in solution containing from 0.1 to 1.0 per cent or more. Here it forms complexes with calcium, magnesium, iron, aluminum, zinc and tin.

At Wakefield, R. I., the soldered joints in the copper feed tank, used to apply the chemical, were dissolved rapidly, as was the galvanizing on a steel drum used to store the solution. Apparently, welded black iron,



Fairhaven Results
The effects of "Calgon" Treatment.

stainless steel, rubber and glass are the best materials for use in contact with strong solutions of hexametaphosphate.

Even the apparent protection given iron pipes when waters of low pH value, containing one or two parts per million of metaphosphate, are passed through them is somewhat in doubt. This statement is made because the chemical is so good a dispersant of iron and other metals that it would prevent the usual red stains from appearing on basins and bowls.

A reading of the report of the round table discussion on corrosion control at the New Orleans meeting of the American Water Works Association in 1938,[4] followed by a reading of the Committee report[5] on the value of sodium hexametaphosphate in the control of difficulties due to corrosion in water systems, published four-and-a-half years later, will give one an idea of the varied and complex character of the problem.

With the above report is a contribution by Dr. F. E. Hale which warns one not to make the mistake of believing that hexametaphosphate prevents the corrosion of iron by soft waters of low pH value, even when the delivered water is of good appearance, free from red water and causes no increase in friction in the mains.

In this connection one must bear in mind the large amount of iron in the pipe system and the small amount in the treated water. In a works discharging 200 million gallons yearly containing 0.10 ppm. of iron dissolved from the mains, the weight of iron lost would amount to only 167 lbs. per annum while the amount of cast iron pipe in the distribution system might weigh from 20 to 30 million pounds, or even more. This does not mean that the possibility of leakage at nipples and joints should be dismissed as negligible or that solution of metal should not be watched. It probably does mean that a better condition than where tuberculation and incrustation with attendant loss in capacity occurs, and which the metaphosphate treatment minimizes or prevents.

Cathodic Protection

During the last few years many waterworks have resorted to electrolytic treatment designed to reverse the ordinary electrolytic action of water. To do this, electrodes are placed in standpipe or filter shell and current is passed from the positive electrode in the water to the negative electrode on the metal, with the result that instead of the corrosive H ion reaching the metal the non-corrosive alkaline OH ion takes its place.

This method, when applicable, is efficient and its cost of operation is low. The chief objection to it, in standpipes particularly, is the effect of ice, which often carries away the electrodes. Fortunately, however, the electrodes can be removed for a few weeks during the winter when corrosive action is lowest. Apparently the protection given the metal during the warmer months of the year is prolonged for a considerable period beyond the time of removal of the electrode.

Naturally, more trouble is experienced when this type of apparatus is used with surface waters than with ground waters, because the temperature of the latter rarely falls below 45° F. as compared with 34° F. for surface waters.

Cathodic protection can also counteract another type of electrolytic corrosion, sometimes called battery action. For example, where two metals, like copper and zinc, are in contact and immersed in water, the zinc goes into solution, an action which countercurrent, afforded by cathodic protection, would neutralize if properly controlled.

In General

In considering the control of corrosion, one must bear in mind that waters vary greatly in their characteristics and action. Consequently, it is extremely difficult to prescribe the best remedy for corrosion control without some actual tests, like those made by the city of Newton. For this purpose, makes of pipe are subjected to the action of treated-and untreated waters under conditions of ordinary use and standing overnight for a sufficiently long period to determine what is best for control of corrosion.

References

(1) Corrosion Control. Prof. Edward W. Moore, *J.N.E.W.W.A.* **55** (1941), 265.

(2) Experiments on the Newton Water and Treatments for the Control of Corrosion. F. W. Gilcreas, *J.N.E.W.W.A.* **48** (1934), 195.

(3) Corrosion Control by Metaphosphate. H. T. Gidley and R. S. Weston, *J.A.W.W.A.* **32** (1940), 1484.

(4) Corrosion Control. Wiggin, Norcom, Glace et als. *J.A.W.W.A.* **30** (1938), 1342-87.

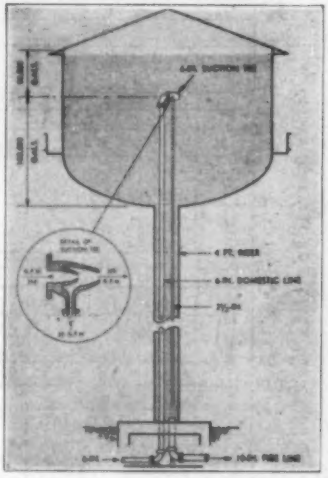
(5) Report of Committee on Water Conditioning Methods to Inhibit Corrosion. E. W. Moore, Chairman. *J.A.W.W.A.* **34** (1942), 1807-1828.

NOVEL SCHEME FOR PREVENTING TANK RISERS FROM FREEZING

Out at Grand Canyon, in Arizona, it gets pretty cold and during the winter season there is but little turnover in the elevated water tank, the chief duty of which is fire sprinkler service during the off resort season. To avoid the solid freeze-up of the tank riser during the low winter turnover period, Santa Fe Railway engineers developed a unique scheme of intermittently circulating water from the bottom upwards through the riser.

The scheme in question has been in successful use now during 15 winter seasons. Briefly, it involves the installation of a suction tee educator (Watson and McDaniel) on the end of the filling pipe. A 2½-in. drop suction line from the educator picks up water at the rate of 30 gpm. from the bottom of the riser and discharges it into the center of the tank to mix with the warmer water. While an ice shell of 2 in. thickness has been found in the riser, the circulating scheme has prevented further ice shell encroachment.

This information originated from G. L. Davenport, Jr., division engineer of water supply, Santa Fe Railway System, Los Angeles.



Schematic Sketch of Riser Recirculating System

"GOVERNMENT" WHITEWASHES

The following formula is commonly known as "Government Whitewash." It is used on lighthouses and other places exposed to the weather, and does not peel off.

Carefully slake one-half bushel (38 pounds) of good quicklime, covering during the process to keep the steam in. Strain the paste while still thick through wire fly screen cloth and add about four gallons of water. While stirring vigorously, pour into the lime mixture a solution made by first dissolving 12 pounds of salt and 6 ounces of alum in about 4 gallons of hot water. Then add one quart of molasses and thin with water to suit requirements.

Another method is:

Using one-half bushel (38 pounds) of good unslaked lime, slake with boiling water and keep covered during the process to keep the steam in. Strain the liquid through a sieve fine enough to retain all unslaked lumps. Dissolve a peck of clean salt in a little water and add to the solution. Boil to a thin paste three pounds of rice and put into the mixture, while hot, and one pound of glue, previously melted over a fire. Add one-half pound of whiting. Mix well and then add 5 gallons of hot water, stirring well. Cover closely and let stand several days.

If the whitewash can be applied when hot, it will go on better and last longer. Coloring matter may be used to vary the tint to suit the taste.

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Anthracite Institute Building
WILKES-BARRE, PENNA.

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Anthrafilt and Its Application

Anthrafilt is made from a selected Pennsylvania anthracite which has been cleaned so as to have a minimum ash. This cleaned anthracite is then screened and classified hydraulically to yield sizes suitable for filter purposes.

Anthrafilt is used as a mechanical aggregate in place of sand and gravel in all kinds of filters, i.e.

Rapid gravity filters	Slow filters
Swimming pool filters	Pressure filters
Hot process softening filters	Oil removal filters
Cold process softening filters	Alkali filters
Mechanical sewage filters	Acid filters
Revolving screen filters	Sewage sludge-beds
Portable filters	Household filters

The entire filter bed may be made up of Anthrafilt of various sizes or only the top layer may be of Anthrafilt over the usual bed of gravel.

Advantages of Anthrafilt

High Filtration Rate: Rates up to 200 mgad are obtainable with Anthrafilt without sacrifice of effluent quality. The accepted average rate with sand is 125 mgad.

Long Filter Runs: The larger, irregular Anthrafilt grains allow less clogging with algae or other fibrous substances. The angular grain surfaces provide greater entrapping areas for the removal of turbidity and bacteria. The differences in shape and specific gravity of the grains, by decreasing classification after back washing, allow the whole depth of the filter bed to be active in the filter operation.

Low Wash Water Costs: The long filter runs and consequent less frequent washing and the low degree of packing after back washing combine to cut the usual wash water requirements at least in half.

No Cementing with Lime, Manganese or Iron: Lime will coat on Anthrafilt but this coating readily flakes off without any cementing action if filters are properly operated. Manganese and iron salts precipitated on Anthrafilt by the lime treatment are easily removed by back washing.

High Degree of Expansion: 50% expansion is obtained with half the back wash velocity required for sand.

Coarse Sizes Can Be Used: The irregular shape and natural filtration characteristics permit the use of much larger sizes with equal results.

Gravel Beds Stay Flat: No ridging or mounding and less cracking and pulling away from side walls during operation.

Low First Cost: Lighter weight per unit volume balances the cost differential between Anthracite and sand and saves on freight and handling charges.

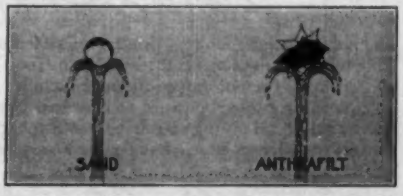
Filtration Characteristics

Anthracite granules are irregular shaped and of varying densities. Weights run about 53 pounds per cubic foot as against 100 pounds for sand. The irregular shapes provide greater porosity resulting in more rapid filtration with no loss in character of effluent and with considerably less loss of head.

The variable densities of Anthrafilt particles cause less classification after back washing and the lighter, irregular shapes allow easier expansion and more effective cleaning.

The greater bulk of Anthrafilt requires less tonnage per filter bed. Attrition losses amount to less than 0.25% per year.

Anthrafilt successfully removes lime, iron and manganese salts and will not form a permanent coating under proper conditions of treatment and filter operation. Lime flakes off easily without cementing and the iron and manganese salts are readily removed by back washing. Oil is easily removed from boiler water after coagulation with ferric sulphate, ferrous sulphate or alum. Anthrafilt can also be used for the filtration of acetic and sulphuric acids and caustic soda solutions. Being insoluble in alkaline waters, Anthrafilt produces silica-free water in hot process water softening.



Upward impulses of water produces greater agitation of angular grains, hence Anthrafilt beds are cleaned more effectively.

Anthrafilt No. 1 is usually made in sizes ranging from effectixe size of .60 m.m. to .80 m.m. the uniformity coefficient is less than 1.75 in all sises. We can make smaller sizes or larger sizes, but for special cases only. The remaining sizes of Anthrafilt are as follows:

No. 2. Anthrafilt—3/32"x3/16"
No. 3. Anthrafilt—3/16"x5/16"
No. 4. Anthrafilt—5/16"x9/16"
No. 5. Anthrafilt—9/16"x13/16"
No. 6. Anthrafilt—13/16"x1-5/8"
No. 7. Anthrafilt—1-5/8"x2-7/16"
The above sizes have 20% tolerance.

ANTHRAFILT ECONOMY

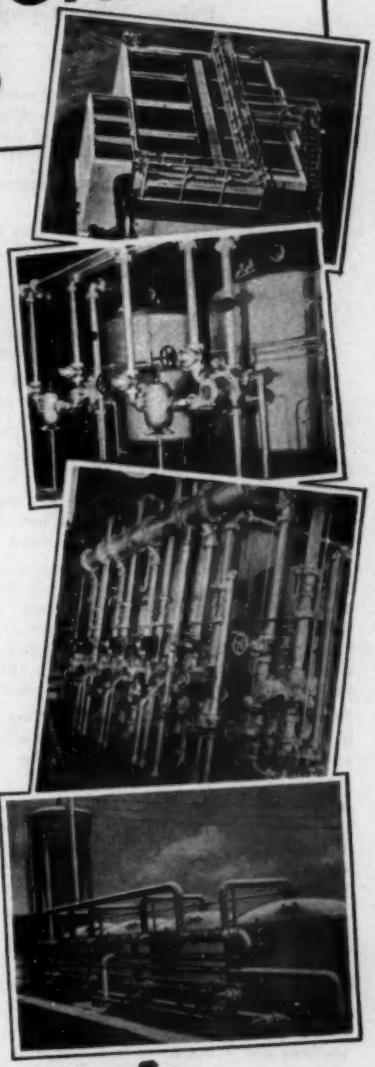
When Used in Existing Filtration Plants

Increased capacity with same plant
Decreased volume of wash water
Lower maintenance cost through elimination of ridging, mounding and air binding.

When Used in New Filtration Plants

Lower plant investment
Lower cost per cubic yard
Lower wash water costs
Lower maintenance costs

4 good reasons why Permutit is WATER CONDITIONING HEADQUARTERS



1. Precipitation

The Permutit® Precipitator offers a most efficient means of removing water impurities. Operating by precipitation, adsorption, settling, and upward filtration, it can save you up to 50% in space, 40% in chemicals, and 75% in treatment time. Applications include softening; removal of turbidity, color, taste, odor, alkalinity, silica, fluorides.

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The ion exchange (zeolite) process for softening or demineralizing water—recognized as the simplest method—was originated by Permutit. Present-day equipment includes fully automatic units with simplified controls, and manually controlled multiport valves, both giving improved performance. Permutit can furnish the correct ion exchanger for any requirements.

3. Iron Removal

Pulp, paper and textile mills, chemical plants, tanneries and other industries requiring water low in iron content depend on Permutit equipment. Permutit processes for iron removal include base exchange; oxidation by manganese zeolites; aeration, settling and filtration; and other processes to meet any specific requirement.

4. Cold lime-soda Treatment

The new Permutit Spiractor® requires far less space and treatment time than earlier types of lime-soda equipment. In the Spiractor, the precipitates accumulate on solid nuclei to form large, heavy granules that can be separated from the water at relatively high flow rates. No sludge is formed; the granules can be disposed of easily.

For full information about these or any other water conditioning processes, write to The Permutit Company, Dept. W 4, 330 West 42nd Street, New York 18, N. Y., or to Permutit Company of Canada, Ltd., 6975 Jeanne Mance Street, Montreal.

Permutit

Water Conditioning Headquarters For Over 37 Years

IRON REMOVAL AND WATER SOFTENING*

By DANIEL J. SAUNDERS

Vice President, The Permutit Co.
New York City

IRON and hardness are two of the most troublesome impurities in water supplies; iron because it stains everything with which it comes in contact and hardness because it wastes soap and forms scale. The tolerance for iron in municipal water supplies is usually stated as being 0.3 ppm., expressed as Fe. This concentration is only a very small fraction of the tolerance for hardness in municipal water supplies (i.e., usually 85 ppm. or 5 grains per gallon, expressed as $CaCO_3$).

If the iron content exceeds this 0.3 ppm., staining becomes a serious problem, for then the bathtub, washbowl and other porcelain fixtures no longer present a spotlessly white gleaming appearance but, instead, develop unsightly, rusty brown or even black stains which can usually be removed only by acid. (Parenthetically, it might be remarked that the common practice of having a bottle of muriatic acid at hand for the removal of such stains is not to be recommended especially where children are concerned and oxalic acid is even worse for it is exceedingly poisonous.)

Iron also stains glassware, tiled floors and walls and other materials. As for laundering in an iron bearing water, this presents such an extremely serious staining problem that laundering in a high iron content water is practically an impossibility. Iron also unites with tannic acid to form ink so tea made with an iron bearing water may, depending on the iron content, develop off colors from a grayish to a diluted black muddy appearance. Of course, as everyone who has used such a water knows, if lemon is taken with the tea, it does bleach out the color. Coffee, also, no matter what brand is used, becomes a rather muddy looking and unpalatable liquid. As for the plain drinking water if the iron content is 1 ppm. or over, an unpleasant metallic taste is very noticeable.

In the water supply distribution system, iron deposits tend to form, especially if the water has come in contact with air in a reservoir or storage tank. At times of heavy draft, these deposits are stirred up with the result that the water coming from household taps may temporarily become very muddy. Iron also favors the growth of various iron bacteria, popularly and collectively known as "iron crenothrix" and these growths have a tendency to break loose in clogging masses which frequently develop bad tastes and odors.

Methods of Iron Removal

In clear, deep well, iron bearing waters, the iron is present as soluble ferrous bicarbonate. Iron present in this form may be removed by (1) aeration, settling and filtration, (2) by cation exchangers operating either on the sodium or hydrogen cycle, or (3) if present in amounts of 1 ppm. or less, by manganese zeolite filters.

Iron in an organic or colloidal form may be present in some surface waters, some shallow well waters and an occasional deep well water. Usually such waters have an appreciable content of organic matter and a high color. Organic iron can not be removed successfully by the methods used for the removal of ferrous bicarbonate but can be removed by coagulation with alum, settling and filtration.

Aeration, Settling and Filtration

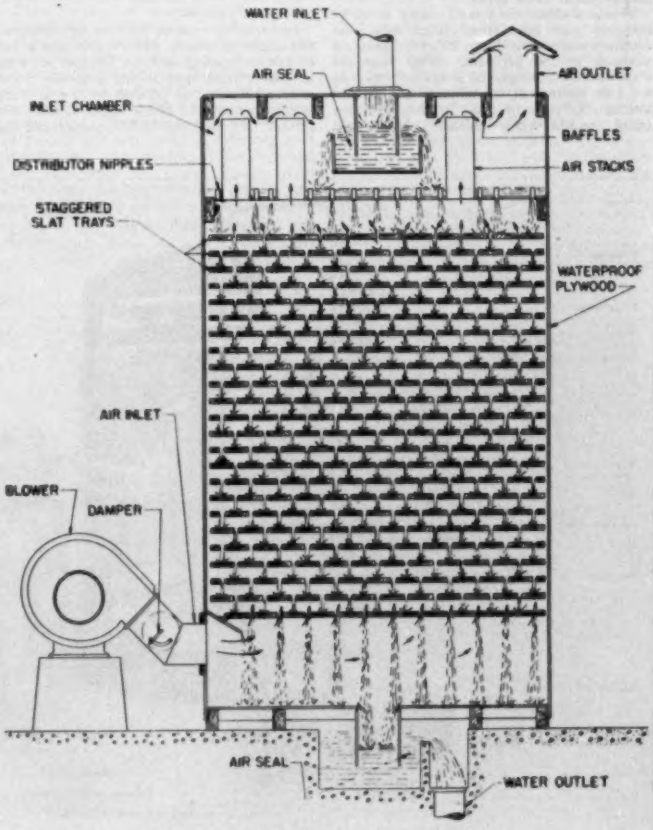
In the first process mentioned above for iron removal, the water is first aerated, which serves both to oxidize the iron and to reduce the content of free carbon dioxide. Certain other oxidizing agents, such as chlorine, may be used, instead of air, but aeration is the process almost universally employed.

Aeration may be carried out in one of several types of open aerators, such as the step aerator, spray aerator, slat aerator, coke aerator, or occasionally, in open basins by blowing air through the water. Also, aeration may be carried out in closed pressure type aerators or aerating filters. In such cases calcite filters may be employed to lower the CO_2 content. Aeration may also be done in a closed type degasifier rectangular in cross-section with one side removable for cleaning.

The oxidizing action of the air converts the soluble ferrous bicarbonate to the practically insoluble ferric hydroxide. With certain waters, this oxidizing action is so slow that it is advisable to speed it up by raising the pH value to approximately 8.2.

As an illustration of the increased speed of oxidation of a ferrous compound at higher pH values, ferrous sulphate, commonly known by the misnomer "copperas," may well be used. Every chemist is familiar with the fact that a solution of ferrous sulphate, which has a low pH value, is fairly stable and that, when exposed to the air, oxidation proceeds at a very slow rate. If such a solution is treated with caustic soda, thus greatly increasing the pH value, oxidation, when air is present, proceeds very rapidly, and insoluble ferric hydroxide is formed.

Similarly in waters of low pH value, containing ferrous bicarbonate, oxidation is slow although, of course, not so slow as



Section Through Rectangular Degasifier
(Arrows indicate air flow)

*All illustrations are of Permutit Co. equipment.

with a solution of ferrous sulphate, which has a very much lower pH value. Therefore, aeration, by reducing the free carbon dioxide content, builds up the pH value and increases the speed of the oxidation. If, in addition, the pH value is increased by an alkali such as hydrated lime or caustic soda, the speed of the oxidation reaction is greatly increased.

The insoluble ferric hydrate produced by this process, may then be removed from the aerated water either by settling or by filtration, or more commonly, by settling followed by filtration. In the latter case, the settling is usually for a comparatively short period, some 15 to 30 minutes.

Filtration is accomplished by the use of sand or anthrafilt filters of either the gravity or pressure type. These are standard filters and as they are operated in the usual manner, no detailed description is necessary. In addition to the usual backwash, surface washers are frequently employed.

Cation Exchange

The removal of ferrous bicarbonate by cation exchange may be accomplished simultaneously with the removal of hardness by cation exchangers operating on either the sodium cycle or the hydrogen cycle. In municipal practice, the sodium cation exchanger process is the one that is almost exclusively used. The cation exchanger may be a green-sand base zeolite, or a carbonaceous or resin type.

When a clear, deep well water is to be softened and also freed from iron, the zeolite water softener may offer the simplest solution to the problem. With most of these waters, the removal is so complete that the iron content of the effluent will usually average 0.1 ppm. or less. In fact, in a few cases, zeolite water softeners have been installed primarily for iron removal, the water softening action being an incidental benefit.

On regeneration with salt, the iron, which has been taken up by the zeolite on the softening run, is liberated as ferrous chloride. This, together with the calcium and magnesium chlorides, is then thoroughly washed to the drain before returning the softener unit to service.

This process will answer for all normal water supplies; for waters of abnormally high iron content aeration, settling and filtration frequently precede zeolite water softeners.

Since the zeolite (or sodium cation exchanger process) yields a water of "zero" hardness, it is customary to by-pass enough hard water to give a mixed effluent with a hardness of about 5 grains per gallon. If the iron content of the raw water is too high to yield a mixed effluent with the desired iron tolerance, the by-pass water should be reendered iron free by separate treatment.

Manganese Zeolite Process

When the iron content is relatively low—1 ppm. or less—and softening is not required, the iron may be removed by means of manganese zeolite filters. The manganese zeolite is a special zeolite manufactured by converting a sodium zeolite to a manganese zeolite by treating it first with manganous chloride and then with potassium permanganate.

In order to remove iron by this process, the water is simply filtered through a bed of the manganese zeolite. This serves both to oxidize the iron to an insoluble form and to remove this product by the filtering action of the bed. These accumulations are removed by periodic backwashings and the oxidizing action is restored by occasional regenerations with potassium permanganate. In this process, only the iron is removed from the water as the manganese zeolite exerts no softening effect.

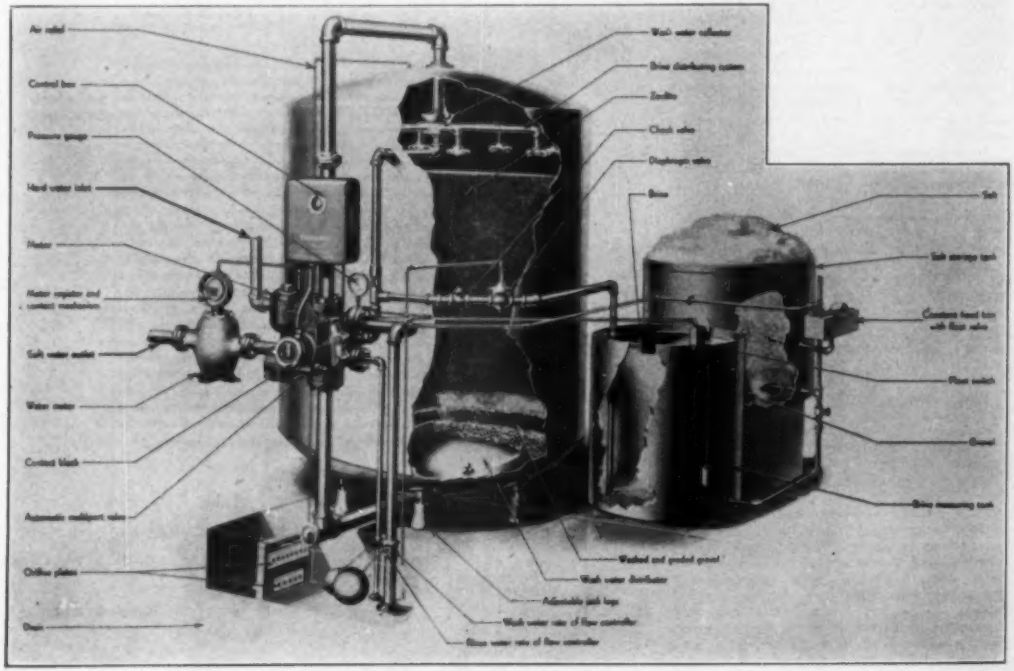
Cold Lime Soda Process

In the cold lime soda (or combination lime zeolite process), ferrous bicarbonate is easily removed with the hardness precipitates by introducing sufficient air into the water to oxidize the iron. If the carbon dioxide content of the raw water is rather low, all that is required is to drop the water, over a couple of steps or baffles, through an air space as it enters the treating tanks. If the water contains a relatively high content of carbon dioxide, then marked economies in the lime dosage may be effected by first passing the raw water through an aerator which may be mounted over the treating tank.

Organic or Colloidal Iron Removal

As previously stated, organic or colloidal iron is not satisfactorily removed by the foregoing processes. Instead it is necessary to coagulate, settle and filter the water. This is not always as simple as it sounds and it usually is necessary to run a series of jar tests to find the optimum conditions, that is, the dosages of coagulant and the pH requirements to secure a good coagulation and the formation of a satisfactory floc. The coagulant which is most widely employed is aluminum sulfate—filter alum—but chlorinated copperas and ferric sulfate are also used.

Chlorination is sometimes of value in removing organic iron but in many cases it seems to have little or no effect. With waters of low mineral content, the use of clay or activated carbon is often of value in aiding floc formation and color removal.



Cut-away of Zeolite Water Softener

Manganese Removal

Manganese, like iron, is an exceedingly troublesome impurity in water but fortunately is much rarer in occurrence. Like iron it may occur as the soluble bicarbonate or in colloidal or organic form. Also its methods of removal are similar, manganous bicarbonate being removed by (1) aeration, settling and filtration, (2) by cation exchangers operating either on the sodium or hydrogen cycle, or (3) by manganese zeolite filters. In removing it by aeration, settling and filtration, however, it is necessary to have a higher pH for its oxidation than is required for iron. In the organic or colloidal form, the method of removal is the same as with iron, that is, by coagulation, settling and filtration.

Municipal Water Softening

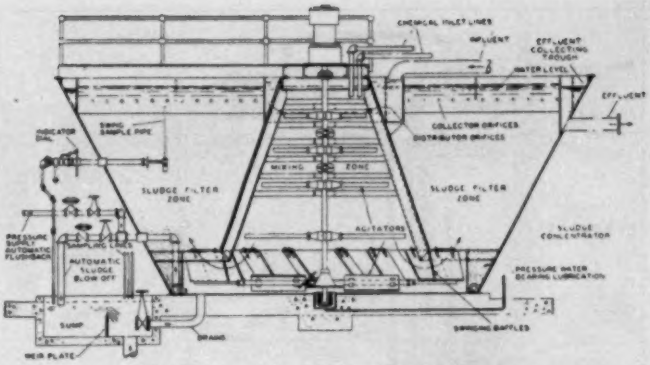
Hard waters, as everyone who has used them can well testify, are expensive nuisances. They waste tons of soaps; decrease the life of washable garments; making bathing, shampooing and shaving thoroughly unenjoyable; scale water heaters, boilers, hot water piping and cooking utensils; and increase costs for fuel, labor, repairs and replacements. While these trials and tribulations are recognized by all users, too few realize that it actually costs much less to soften a hard water than to continue using it. Surveys however have proven that, on the average, the costs for the materials used in softening a municipal water supply are only about one-third the cost of the soap wastage incurred in using the hard water.

There are three processes which are used in softening municipal water supplies. These are:

1. The zeolite (or sodium cation exchanger) process
2. The cold lime soda process
3. The combination lime-zeolite process

Zeolite (or Sodium Cation Exchanger)

In the zeolite (or sodium cation exchanger) process, the hard water is softened by merely flowing it through a bed composed of a granular sodium zeolite or an organic sodium cation exchanger. This removal of the hardness is so complete that the softened water is usually termed "zero water" meaning a water that is practically zero in hardness. After a definite amount of hardness has been abstracted, the bed is treated with a predetermined amount of common salt brine, which removes the hardness from the bed and restores it to its original sodium condition.

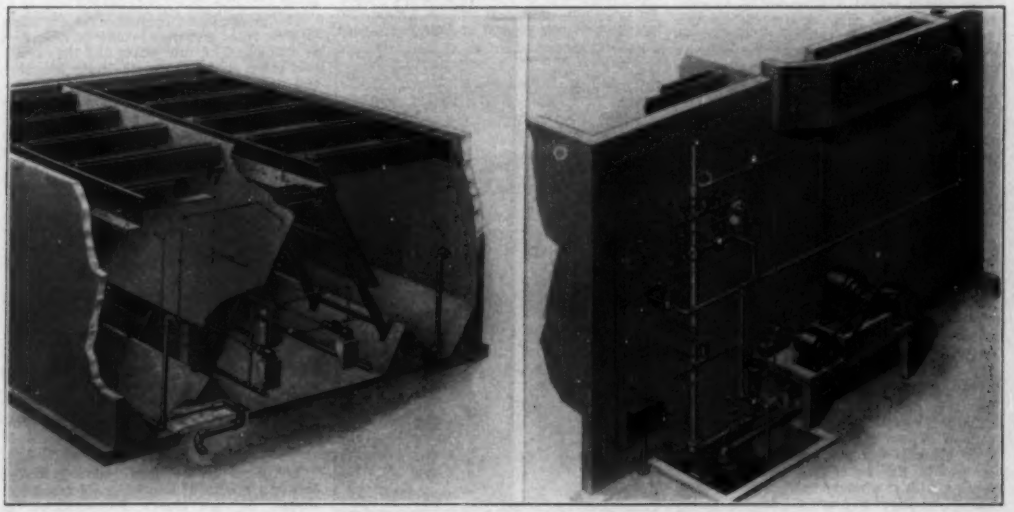


Line Drawing of Permutit Spaulding Precipitator

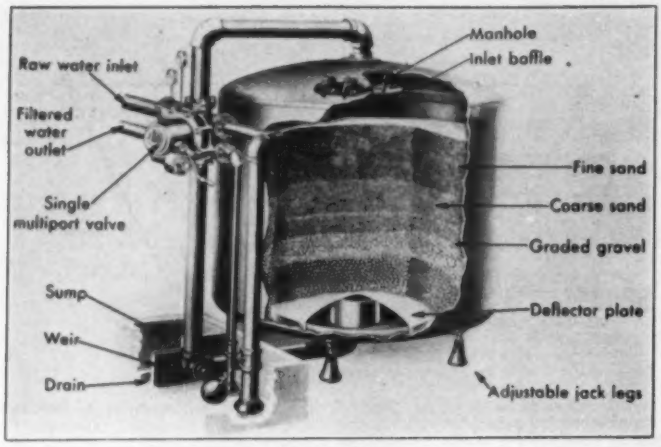
This restoration process is known as "regeneration" and consists of three steps: backwashing, salting and rinsing. The backwashing serves to loosen, cleanse and hydraulically regrade the bed. The salting serves to remove the hardness and simultaneously to restore the bed to its original sodium state. The rinsing serves to remove the excess salt and soluble by-products—calcium and manganesium chlorides—and wash them down the drain. These cycles of softening and regeneration may be repeated indefinitely as the wear and tear on the bed is very slight—usually under 3 per cent per year. Therefore only a slight addition of new material is required annually to keep the bed performing at its full rated capacity.

The softening plant may consist of a single softener unit or batteries of two or more units. In the latter case the units are usually of such a size that, when one unit is being regenerated, the other unit or units carry the full load. The softener units used in municipal practice may be either of the pressure type or the gravity type. In the pressure type, the bed is enclosed in a steel shell; in the gravity type, the bed is enclosed in a rectangular concrete shell. In both types, the bed is supported by several layers of graded gravel overlying an underdrain system. This serves to collect and pass the softened water to the service lines during the softening run; to distribute the backwash water during the backwashing operation; and to collect and pass to the drain the waste brine and rinse water during the salting and rinsing operations.

Zeolite (or sodium cation exchanger) water softeners are available in fully automatic, semi-automatic or manually operated designs. In the fully automatic pres-



Cut-away View of Horizontal "Precipitator"
Left—Interior; Right—Front Wall



Pressure Filter

sure type softener, a motor operated valve is usually mounted on the front of the softener unit. In the gravity type softener, a motor operated pilot valve is used to regulate the hydraulically operated gate valves on the softener unit.

In either case, the principles of operation are the same. A water meter on the soft water outlet line is equipped with an electric contact head and an automatic resetting device. At the end of the softening run, a contact is made establishing an electric current which rotates the valve to the wash position. The length of the backwash period is governed by an electric time switch.

At the end of the backwash period, a current is again established which rotates the valve to the brine position. In this position, a predetermined volume of saturated salt brine is admitted to the softener, this volume being governed by an electric float switch. After the brine has been admitted the valve is rotated to the rinse position. The rinsing period is governed by an electric time switch and, at the end of this period, the valve is rotated to the soften position, which again places the softener unit in operation. In the meantime the resetting device on the meter has automatically reset it for the next softening run.

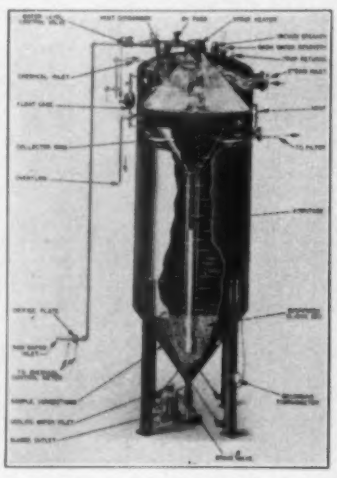
Semi-automatic operation is used principally on waters which may suddenly vary in composition. The semi-automatic units are similar to the fully automatic in operation with the single exception that the regeneration and return to service operations are initiated by the operator instead of by the meter. Manual operation is performed by the operator opening and closing the proper valves in sequence, timing the backwashing and rinsing operations and measuring the drawdown during the salting operation. The valves used may be either of the conventional type or the hydraulic type, the latter being operated from a control table.

In municipal practice, effluents having a hardness of 4 or 5 grains per gallon are usually desired. With the zeolite (or sodium cation exchanger) water softener, such effluents are obtained by softening a portion of the water to "zero" and then mixing with it whatever proportion of hard water is required to reach the desired quality of effluent. If the raw water contains appreciable amounts of iron, it is the usual practice to treat the raw water and remove its iron content before mixing it with the softener effluent. (See Iron Removal Section above.)

Cold Lime Soda Process

In the cold lime soda process, the hard water is treated with lime or lime and soda ash, added in such proportions and amounts as to precipitate the bulk of the hardness in the forms of calcium carbonate and magnesium hydroxide. The function of the lime is to remove free carbon dioxide; to change the calcium bicarbonate to the insoluble carbonate and when magnesium hardness reduction is required, to precipitate it as magnesium hydroxide. The function of the soda ash is to convert the chlorides or sulfates of lime and magnesia to the carbonates.

In waters which contain little or no sulfate (or non-carbonate) hardness, treatment with lime alone will be sufficient to reduce the hardness to the required tolerance. On the other hand if the non-carbonate hardness exceeds some 3 grains per gallon, the use of soda ash as well as lime is required to produce a 5 grain per gallon effluent. In either case, the addition of a small amount of a coagulant—usually about 20 ppm. of aluminum sulfate—is desirable in order to form an easily settled floc.



Hot Process Softener—Sludge Blanket Design

Sludge Blanket Softeners

In the older or so-called "conventional" cold lime soda water softeners, treatment and settling was effected in large settling tanks or basins and the effluent was usually recarbonated before passing through the filters in order to prevent "growth" of the filter granules and "after deposits" in the distribution system. In the newer, sludge-blanket type of equipment, the treated water, by being brought in intimate contact with previously formed precipitates, is brought into chemical balance so that recarbonation is unnecessary unless a lowering of the pH value is required.

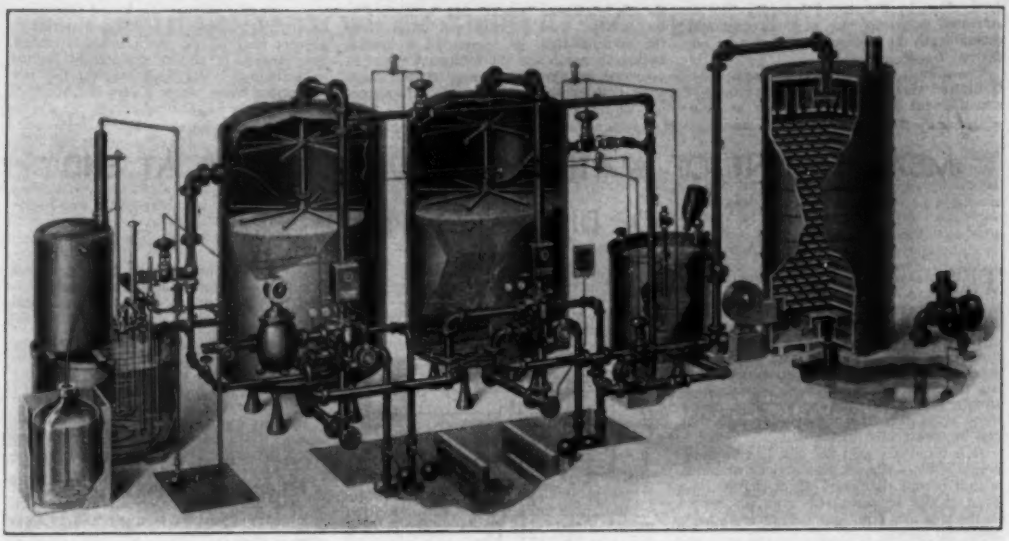
For the purpose of explaining this system, the "Permutit Spaulding Precipitator" will be described. The "Precipitator" is available in two basic types, the vertical and the horizontal and in sizes ranging from 10 mgd. per unit down to small units for carbonated beverage plants and other such uses, with capacities of only a few thousand gallons per day. Also it is possible to convert many of the older settling basins and tanks to the "Precipitator" type by remodeling their interiors and thus increasing their efficiencies, lowering their lime requirements and increasing their capacities.

The vertical "Precipitator" may be described as a cone, cut in half, the smaller portion, with the largest diameter downwardly disposed, being placed in the center of the larger portion, with the largest diameter upwardly disposed and with, of course, a space between the lower rim of the downcomer and the bottom of the tank. This downcomer is equipped with a centrally disposed, vertical agitator. The horizontal "Precipitator" differs from the vertical type in that the outer chamber is a rectangular concrete tank; that the inner chamber or downcomer is formed by sloping partitions and that two horizontal agitators are employed in the inner chamber, these being driven by a motor placed in a drive pit at one end of the Precipitator.

The principles of operation are the same in both types and may briefly be described as follows: The raw water and the chemicals enter at the top of the inner chamber and pass downwardly through it, the agitator serving to thoroughly mix the chemicals with the water and to keep the precipitates, formed by the reactions, in suspension. Emerging at the bottom of the inner chamber, the treated water flows upwardly through a suspended blanket of previously formed sludge. As the cross-sectional area of this outer chamber increases from bottom to top, the vertical velocity of the rising water constantly decreases until a level is reached beyond which it cannot lift the precipitates. In practice, there is a clear line of demarcation between the top of the sludge blanket and the clear effluent rising above it to the outlets.

The intimate contact thus obtained between the precipitates and the water results in a complete utilization of the added lime; elimination of super-saturation and after-precipitates; and, due to the filtering action of the sludge blanket, the production of clearer effluents and longer filter runs.

The depth of the sludge blanket is kept between specified limits by bleeding off sludge, through sludge concentrators, at approximately the same rate at which new sludge is formed. These sludge concentrators are relatively small compartments in the



Automatic Demineralizing Plant with Degasifier

bottom of the outer chamber through which there is no upward flow of water and in which, therefore, the requisite part of the sludge settles and concentrates to about 10 per cent solids.

In municipal practice, the effluent from the "Precipitator" is filtered before passing to the clear well. The filters used are usually of the gravity type and therefore need no detailed description. In addition to their use in the cold lime soda water softening process, "Precipitators" may be used for the coagulation of turbid or colored waters.

Combination Lime Zeolite Process

In the combination lime zeolite process, the water is first treated with lime to reduce the bicarbonate hardness. The filtered effluent is then passed through a zeolite (sodium cation exchanger) water softener to remove the noncarbonate hardness and residual carbonate hardness. With waters containing appreciable amounts of noncarbonate hardness, this process shows very economical operating costs as the cheapest method of removing bicarbonate hardness is with lime and the cheapest method of removing noncarbonate hardness is with zeolite.

Further advantages with this process are that it reduces the alkalinity and total solids content and that, where iron removal is concerned, the iron can be removed in the first stage of the process by introducing enough air to oxidize the iron to the ferric state. In using this process for municipal water softening, the usual 5 gpg. effluent may be obtained by mixing the requisite portion of the filtered lime treated water with the zeolite effluent.

The system used consists of a cold lime softener plus filters plus zeolite water softeners. If the pH value of the lime treated water is too high, a slight recarbonation will serve to reduce it. If the raw water is an iron or manganese bearing water, or, if the free carbon dioxide content is high, an aerator is employed ahead of the cold lime softener. This may consist of a coke tray or wood slat tray aerator; or, if only a slight aeration is needed, running the water over a few steps or baffles before it enters the cold lime softener will be sufficient; or, the air may be introduced by an air grid and compressor in a compartment ahead of the lime treatment.

Demineralization Process

While the hydrogen cation exchanger process, the ion exchange demineralizing process, find other uses than in the treatment of municipal water supplies, a brief description of them may be of interest. In the hydrogen cation exchanger process, the cation exchangers used are of the organic or non-siliceous types. These organic cation exchangers may, when regenerated with salt, be used in the same manner as the siliceous zeolites. Their most interesting use, however, is on the hydrogen cycle.

On the hydrogen cycle, the cation exchanger is regenerated with acid, usually sulfuric acid. The hydrogen thus introduced into the cation erchanger will exchange hydrogen for calcium, magnesium and sodium ions.

If a water containing nothing but the bicarbonates of these metals is passed through a hydrogen cation exchanger, the calcium, magnesium and sodium will be completely removed and nothing but free carbon dioxide will be left in the effluent. As the carbon dioxide is easily removed by aeration, such an aerated effluent would be practically the same as distilled water in composition.

However, if sulfates and chlorides are also present, these would appear in the effluent as the corresponding acids. These may be neutralized by the addition of soda ash or by mixing with the requisite quantity of water softened on the sodium cycle.

On the other hand, if complete removal of the sulfates and chlorides is required, then the effluent from the hydrogen cation exchanger is passed through an anion exchanger which completely removes the sulfuric and hydrochloric acids formed by the hydrogen cation exchanger. The carbon dioxide is then removed by aeration resulting in an effluent equivalent to a distilled water. As the cost of demineralization is only a very small fraction of the cost of distillation, this process is now coming into very extensive use wherever a water of such high quality is required.

Hot Lime Soda Process

The hot lime soda process, too, may be of interest, although not used for municipal softening. It is confined almost exclusively to the softening of boiler feed waters as the process is carried out at the boiling point. The softener consists of a tall enclosed steel tank designed usually to withstand a pressure of about 10 psi. In the top of the softener is a spray heater, which heats and deareates the water to less than 0.3 ml. per liter of dissolved oxygen.

The lime and soda ash are fed to the hot water in the top of the softener where it reacts with the hardness producing a sludge. In the newer sludge blanket type design, the water flows through a downcomer in the center of the softener and then rises through a blanket of this suspended sludge. In the older types, the flow was downward to a short distance above the bottom where the treated water was drawn off through a cylindrical uptake while the sludge settled to the bottom.

The sludge blanket type has rapidly come into popular favor particularly where the silica content, as well as the hardness, requires reduction or removal and it is built in a number of designs for handling makeup alone or both makeup and various amounts of condensate and for either a deaeration to 0.3 ml. per liter of dissolved oxygen or comp'ete deaeration to less than 0.005 ml. per liter. In the latter case, the complete deaeration is effected by a clever use of the steam required for the primary heater; this steam being blown through the hot, softened and partially deaerated water in a deaerator compartment before being used in the primary heater.

The hot process softener will reduce the hardness to below 1.5 gpg. (25 ppm.) by the use of lime and soda ash alone and to as little as 1 or 2 ppm. when phosphate also is

used. Also, by the use of dolomitic lime or activated magnesia, the silica content may economically be reduced to practically any desired figure.

The effluent from the hot process softener is filtered through pressure filters using a non-siliceous filter medium such as "Anthrafilt." These filters are periodically backwashed with hot softened water from the settling tank by means of a special backwash pump and the backwash water is returned to the top of the settling tank, thus recovering it. Since the process is carried out at temperatures around the boiling point, the softener tank and filters are usually lagged with insulating material to prevent heat losses. As previously stated, this process is almost exclusively limited to softening boiler feed waters, the few exceptions being where a very hot, softened process water is required.

MEASUREMENT OF WATER BY CIRCULAR ORIFICE AT END OF DISCHARGE PIPE

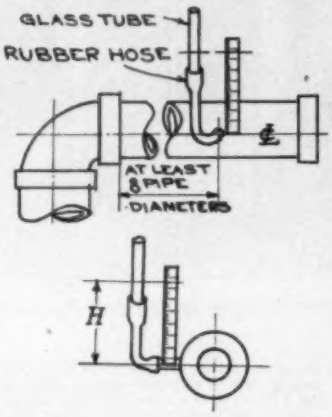
THE measurement of water flowing thru pipe lines by means of a circular orifice has been proven quite accurate, and experiments have demonstrated that a thin plate circular orifice installed at the end of a pipe line gives a rapid and accurate method for measuring such flows; the instruments being light and easily attached, permits of a simple method of testing pumping plants more accurately than the average weir that can be constructed in the field.

It is necessary that the pipe line be horizontal with no elbows, obstructions, or bends within 8 pipe diameters of discharge; the head should be measured from the center of the pipe at a point one foot or more back from the orifice.

The accompanying curve gives the discharge for 13 inch orifice on 15¼" inside diameter pipe, the formula being:

$G = KA\sqrt{2gh}$

Where G = Gallons per minute
A = Area of orifice in square inches



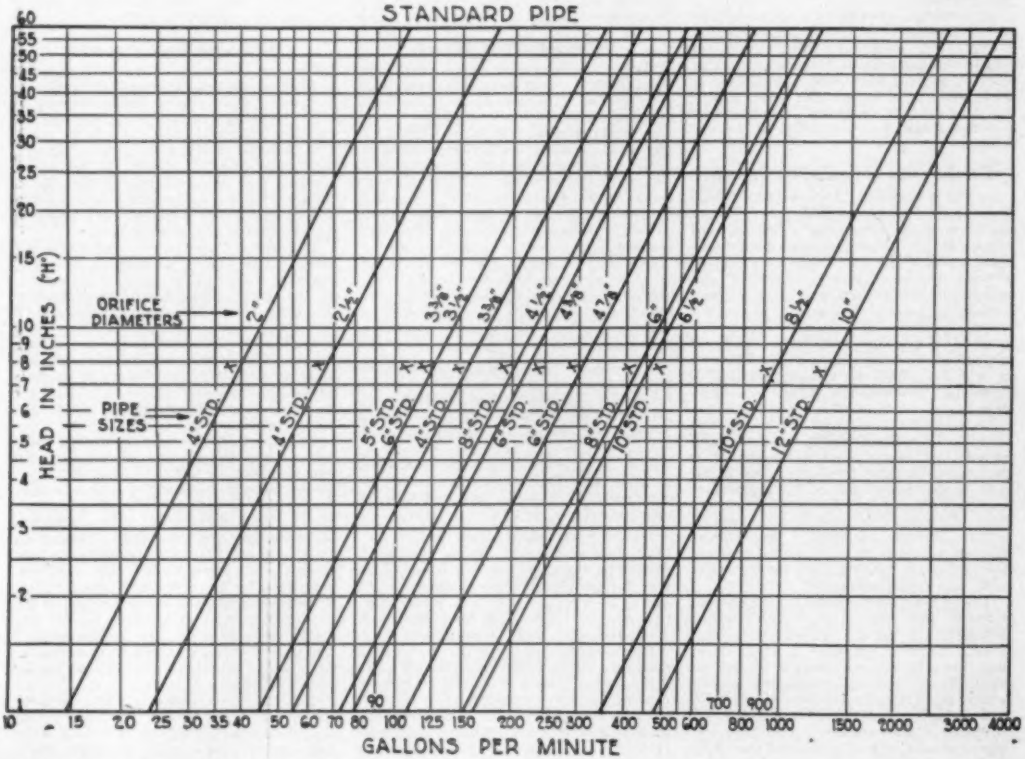
K = Constant depending on size of pipe and size of orifice.
H = Head in inches above center of discharge.

In calibrating these orifices a well constructed weir was used and the maximum variation of "K" was less than 3%. An average "K" was then taken from which these curves were constructed.

It is necessary that the orifice be running full of water and that "H" be at least one inch above top of the pipe for accurate results.

The head is measured by drilling and tapping for ⅛ in. pipe connection on the side of the discharge pipe one foot or more back of orifice, the hose connection installed and the height measured with an ordinary rule; the hole can then be plugged with an ⅛ in. pipe plug. It is very important that the ⅛ in. nipple does not extend inside the inner wall of the pipe and should be absolutely flush.

Peerless Pump Bull.



FLUORIDATION OF PUBLIC WATER SUPPLIES*†

By F. J. MAIER
Sr. San. Engr., U. S. Public Health Service, Bethesda, Md.

SOME of the most important contributions to the improvement of public health have been made through the application of procedures designed to remove from drinking waters substances injurious to health. Conversely, the discovery of the role of optimum amounts of fluorides in water has led to the concept that the treatment of drinking water might include the addition of specific substances to prevent disease.

Fluorides† are added to drinking water in order to reduce tooth decay. Where necessary, fluorides are removed from water to prevent dental fluorosis. That the removal of fluorides from water will prevent one disease, while their addition to water will prevent another, entirely different defect from developing, is one of the most curious reversals in the history of water supply engineering.

The role of fluorides as the causative agent of dental fluorosis has been known since 1931, although a description of the lesion had been reported 30 years previously. Fluorosis in its moldest forms produces chalky-white spots or causes the entire crown surfaces to turn chalky white. As fluoride concentrations increase, secondary, brown to black stains appear, and, in the severest cases, the enamel shows a pitted and eroded surface which chips and crumbles easily, resulting in a degree of enamel attrition not commensurate with the chronological age of the individual affected.

Fluorosis becomes evident in children if, during the period of enamel calcification, they have been consuming water which contains more than about 1.5 ppm. of fluoride ion. The effects of fluoride concentrations in water will differ, of course, as the amounts of water consumed and the susceptibility of individuals vary. The lesion becomes more severe as the concentration of fluorides increases, until, at 6.0 ppm., practically all children are affected, many with a marked to severe type causing considerable disfigurement.

On the other hand, it has been shown that 1.0 ppm. fluoride naturally occurring in water is sufficient to decrease the incidence of dental caries by more than 60 per cent. The accompanying degree of fluorosis is negligible.

Studies are now in progress to demonstrate that this reduction in caries incidence can be duplicated by artificially adding fluorides. The oldest of these studies, started in January 1945 at Grand Rapids, Mich., with 1.0 ppm. fluoride, has shown recently that the incidence of caries experience among children aged five to seven is practically the same as that in children in the same age groups at Aurora, Ill. (Fig. 1). The fluoride content of the Aurora water supply is 1.2 ppm. There are no discernible reasons for suspecting that each successive yearly examination at Grand Rapids will not follow the same trend. There is no evidence, either, that 1.0 ppm. of the fluoride ion naturally occurring in water is different in effect from the same concentration derived by dissolving a fluoride compound in water.

Similar caries reductions have been noted at other places where fluorides are being added. For example, at Newburgh, N.Y., where fluoridation was started in May 1945, a 30 per cent reduction in caries in permanent teeth was found among children in the six-to-twelve age group.

At Sheboygan, Wis., where fluoride was first added in February 1946, a 20 per cent reduction was shown in three years. At Brantford, Ont., a 22 per cent reduction in decay rates of the permanent teeth was reported after 40 months of fluoridation. There are, in addition, more than 40 other places in the United States where fluoridation is practiced, most of them being in Wisconsin.

Fluoride Concentration

In most of the earliest fluoridation projects, a concentration of 1.0 ppm. or slightly higher has been used. This rate of feed is based essentially on the conclusions reached by H. T. Dean of the U.S. Public Health Service in his study of 7,257 selected children in 21 cities in Illinois, Indiana, Ohio and Colorado (1, 2). A fluoride concentration of 1.0 ppm. is probably the optimum for this north central area of the country, but not necessarily the best for all areas.

The severity of fluorosis and the degree of caries protection varies (within limits) with the fluoride intake. The quantities of fluoride ingested are generally dependent on the amounts of water consumed. Consumption, in turn hinges in part on the temperature and relative humidity of the locality. It has been suggested that the optimum fluoride rate of feed is the highest concentration which will not produce more than about 10 per cent fluorosis. A 10 per cent incidence of endemic fluorosis represents the very mildest degree and, therefore, is of no esthetic consequence; it is in fact, generally unrecognizable.

What is needed, then, in order to determine the optimum rate of feed for a given locality, are sufficient data from places where public water supplies contain 0.5-1.5 ppm. fluoride; where the fluorosis prevalence is about 10 per cent among children at least 14 years of age; where reliable data on humidity and mean annual temperatures are available; and where there is a sufficient number of children to justify a valid conclusion. Unfortunately, such data have been obtained from too few such communities to formulate definite conclusions. Nevertheless, all available information has been plotted in Fig. 2 to indicate very roughly the possible relationship between the optimum fluoride content of municipal water supplies and mean annual temperatures (1, 2). Also shown in Fig. 2 is the percentage prevalence of fluorosis found at the various cities noted.

Perhaps the most that can be ascertained now from such a curve is that those places which experience a mean annual temperature of more than 55°-60°F. should supply water containing less than 1.0 ppm. fluoride. Mean annual temperatures alone may not, however, be the best basis for estimating water consumption in some communities. For example, more water may be consumed in an area where the days are very hot and the nights cold than in a locality with a more uniform temperature but the same mean annual temperature. Relative humidity is also an important factor to be weighed. Data on considerably more communities will have to be accumulated before this suggested curve can be regarded as entirely practicable. Eventually it will be possible to construct a graph from which, when the local mean annual temperature (or mean daytime temperature) and relative humidity are known, the optimum fluoride can be read directly.

At Charlotte, N.C., Z. M. Stadt, Dental Officer, City Health Dept., has concluded than an equivalent of 0.9 ppm. fluoride should be added. The mean annual temperature at Charlotte is 61.9°F. As shown in Fig. 3, Stadt and R. S. Phillips, Supt., Charlotte Water Dept., have gone further and correlated average monthly temperatures, probable variations in water intake (based on carbonated-beverage sales) and the resulting variable fluoride feed (3).

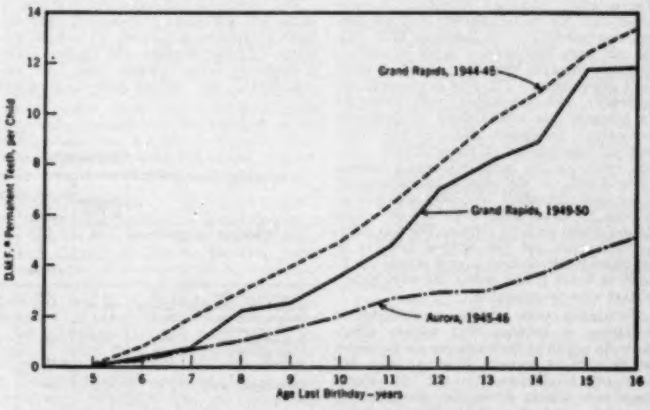


Fig. 1. Caries Experience at Grand Rapids and Aurora

*Decayed, missing and filled.

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†Throughout this article, where the author speaks of fluoride he refers to the fluoride ion; fluorides refers to a fluoride salt containing the fluoride ion.

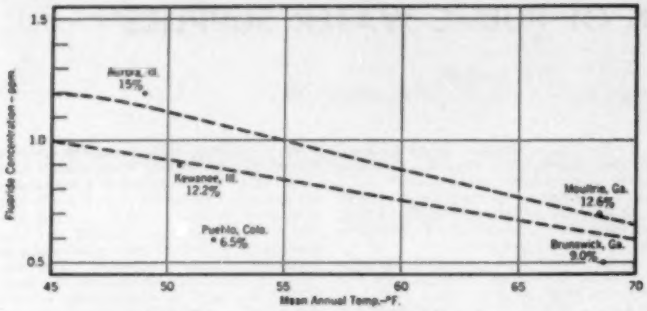

Fig. 2. Temperature and Optimum Fluoride Content

A fluoride concentration which is set too high, although providing increased caries protection, will cause an excessive amount of fluorosis and, possibly, result in an embarrassing series of lawsuits. One such incident might well discourage fluoridation projects scheduled for many other communities.

Fluoride Compounds

Early fluoridation projects employed sodium fluoride as the source of fluoride. This compound was adopted because it was commercially available in large quantities, was convenient to use and had a solubility which was relatively high and constant over wide temperature range; also, studies on its toxicity and physiological effects had been completed.

Obviously, there are many other compounds which might be used. Table 1 lists, in order of solubility, those fluoride compounds which, because of their present availability, cost, purity and freedom from ordinarily undesirable ions, appear to be suitable for fluoridation. There are, of course, other compounds (potassium fluoride, magnesium fluoride, sodium bifluoride) which may become more attractive in the future. Some fluorides have obvious advantages over others. For instance, the calcium salt is the cheapest source of fluoride, but because of its insolubility it would be difficult to feed. It might well become the prefetred fluoride, however, in some of the larger plants, where it could be fed directly into the water.

The acid fluorides (particularly hydrofluoric acid), although considerably more expensive, can be fed directly without considering solubility. At Madison, Wis. (4), 70 per cent hydrofluoric acid is used in order to conserve space in a series of small well pumphouses. The acid is proportioned indirectly with a solution feeder. Instead of pumping the acid (which is extremely corrosive), the feeder forces an inert mineral oil into the top of the acid tank. The oil, riding on the acid, displaces a volume of acid equal to the amount of oil pumped. Corrosion difficulties in piping and fittings appear to have been overcome by using Monel metal or hard rubber. Because of its corrosiveness and the danger inherent in its handling, hydrofluoric acid should not be used in water plants unless the most expert supervision is available.

Balancing cost against convenience in handling, it appears that sodium silicofluoride might be the most promising source of fluoride at present. Racine, Wis., has been able to purchase it at 3.23c per pound delivered, which, from the standpoint of cost per pound of available fluoride, makes it about one-fifth as expensive as the fluoride obtained from sodium fluoride.

Most of the sodium silicofluoride produced today is a by-product of the phosphate salt and phosphate fertilizer industries. It is derived from phosphate rock (containing calcium fluoride and fluoapatite) which has 3-4 per cent fluorine. Silicon tetrafluoride, evolved when the rock is acidified, can be converted to hydrofluosilicic acid by reacting with water, but in most plants it is allowed to escape into the atmosphere or is absorbed in waste water. By reacting the hydrofluosilicic acid with a sodium salt, sodium silicofluoride is formed. It is estimated that over eight times the present annual consumption (10,000 tons) of sodium silicofluoride could be produced at the present rate of phosphate salt production (5). It appears then, that, from this source alone, there is enough fluoride now available to add 1.0 ppm. to the water consumed by the entire population of the United States. Recent, unpublished studies by F. J. McClure have shown that the availability of the fluoride ion in sodium fluoride is comparable to that in sodium silicofluoride.

Sodium silicofluoride is a crystalline, nonhygroscopic salt with a molecular weight of 188.05, a density of 2.679, a density of saturated solution of 1.0054 and a pH of saturated solution of 3.5-4.0. The hydrolysis permits direct analytical determination by titration with a standard alkaline solution. The solubility at various temperatures is shown in Table 2. Two grades are available commercially, regular (72 lb. per cubic foot) and fluffy (55 lb. per cubic foot). Both sodium fluoride and sodium silicofluoride can be purchased in 100-lb. bags, 375-lb. fibre drums and 425-lb. barrels.

The relatively low and variable solubility of the salt will make it somewhat more difficult to feed as accurately as sodium fluoride. Solution feeders will require either a relatively large solution tank (219 gal. (at 25°C.) per million gallons of water treated) or a smaller tank with the salt fed as a slurry. Feeding a slurry requires constant agitation of the mixture and a design for the feeder valves and slurry lines which will prevent clogging. If hot water is continuously available (particularly at softening plants employing carbonation), a constant high-temperature water can be utilized, which will result in lower solution water requirements. For dry feeders, a larger solution box requiring more water will be necessary, as compared with a feeder using sodium fluoride.

Fluoride Feeders

Devices for feeding fluorides, accurately have generally been adapted from those machines originally designed for feeding a variety of chemicals in water treatment and industrial plants. Feeders can be broadly divided into two types: [1] solution feeders, where a measured quantity of accurately prepared fluoride solution is delivered during a specified period; and [2] dry feeders, where a predetermined quantity of the solid material is delivered during a given time interval. The choice of a feeder depends on the rate at which fluoride is required. This rate, in turn, is determined by the water consumption and the fluoride content of the untreated water. Solution feeders are used for smaller supplies and dry feeders for larger ones. There is, of course, a wide area within which either type would be equally successful.

Solution feeders in single units have heretofore been used for supplies delivering up to about 2.0 mgd. Such units have a maximum delivery rate of about 400 ml. per minute. When sodium fluoride is used, the solution strength is usually brought up to 3.0-3.5 per cent, although this concentration can be made much lower, if desired, where the water supply is very small. If excessive amounts of calcium or magnesium are present in the solution water, calcium fluoride or magnesium fluoride will precipitate, settle out and become lost. To prevent this in a saturated fluoride solution, the solution water should not contain more than 20 ppm. calcium (50 ppm. as $CaCO_3$) at 25°C. The concentration of magnesium

TABLE 2

Solubility of Sodium Silicofluoride

Temp. °F.	Solubility oz./gal.
32	0.58
50	0.72
77	1.02
95	1.25
104	1.40
113	1.50
122	1.62
131	1.78
140	1.98
176	2.60
212	3.26

TABLE 1

Characteristics of Fluoride Compounds

Chemical	Formula	Fluoride in Pure Chemical	Purity of Commercial Chemical	Fluoride in Commercial Chemical	Solubility at 25°C. g./100 ml.	Fluoride in Satd. Soln. at 25°C. ppm.	Amt. of Soln. per mil.gal. of Water (25°C., 1.0 ppm. F^-) gal.	Cost per Pound ¢	Cost per Pound of Commercially Available F^- ¢
		per cent							
Calcium fluoride	CaF_2	48.8	98.0	47.7	0.004	19.1	52,300	2.0	4.2
Sodium silicofluoride	Na_2SiF_6	60.64	98.8	60.0	0.762	4,572	219	3.23	5.4
Sodium fluoride (90 per cent)	NaF	43.3	94	42.5	4.05	17,200	58.2	10.5	24.8
Sodium fluoride (98 per cent)	NaF	45.3	98	44.4	4.05	18,000	55.6	11.5	26.0
Hydrofluosilicic acid	H_2SiF_6	79.0	30	23.7		Fed directly	3.33*	5.0	21.0
Hydrofluoric acid	HF	95.0	60	57.0		Fed directly	1.42†	13.5	23.7

* Specific gravity 1.26.
† Specific gravity 1.24.

may reach 50 ppm. (210 ppm. as $CaCO_3$) at the same temperature before precipitation occurs.

A more concentrated solution of sodium fluoride can be obtained with a recently developed saturator, in which water passes down through a bed of crystalline sodium fluoride (6). The sodium fluoride rests on a straining device so that a saturated solution of the fluoride can be withdrawn by the feeder. For this purpose, a sodium fluoride of larger particle size (20-40 mesh) has been produced which permits an increase in the rate of flow of water through the bed. The withdrawal rate must not exceed the rate of flow through the fluoride. A similar grain size for sodium silicofluoride would be most desirable.

Where a community is supplied with water from several different sources, the use of several small solution feeders is more economical than any attempt to bring the supplies together at a central point for treatment. Multiples of these single units may also be used at a central point. In such situations, however, a larger solution tank is required or the solution must be made up more frequently. In general, it has been more economical and convenient to use dry feeders when the daily consumption exceeds about 2.0 mgd. Solution feeders cost about $250 without auxiliary equipment.

Solution feeders of various capacities and refinements in construction can be obtained from: Graver Water Conditioning Co., New York; Hills-McCanna Co., Chicago; Infilco, Inc., Chicago; Lapp Insulator Co., Leroy, N.Y.; Milton Roy Co., Philadelphia; Morse, Boulger Destructor Co., New York; Omega Machine Co., Providence, R.I.; Permutit Co., Inc., New York; Proportioneers, Inc., Providence, R.I.; T. Shriver and Co., Inc., Harrison, N.J.; and Wallace and Tiernan Co., Inc., Newark, N.J.

Dry feeders are of two general types: [1] volumetric feeders which deliver a measured volume of dry chemical within a given time interval; and [2] loss-in-weight feeders (gravimetric) which deliver a measured weight of chemical within a given period.

Single volumetric feeders have been used for supplies delivering between 2.0 and 5.0 mgd. Disk type volumetrics, however, can deliver up to 25 lb. of sodium fluoride per hour and roller types, up to 18 lb. per hour. If these maximum rates could be used, up to 32.6 mgd. could be treated. The volumetric feeder is utilized while resting on scales. The hopper holding the dry chemical may be fitted with a dust collecting system. These feeders cost $350 or more.

Volumetric feeders of sufficient accuracy for fluorides are manufactured by: B. F. Gump Co., Chicago; Infilco, Inc., Chicago; Jeffrey Manufacturing Co., Columbus, Ohio; Omega Machine Co., Providence, R.I.; Permutit Co., Inc., New York; and Wallace and Tiernan Co., Inc., Newark, N.J.

Gravimetric, loss-in-weight, feeders have been used for the larger supplies. They are capable of feeding up to 5,000 lb. per hour, which exceeds the greatest demand on any supply in the United States. On the other hand, they are capable of feeding accurately as little as 10 lb. per hour. They are fitted with solution boxes and their built-in weighing mechanism provides a constant indication of the rate of feed. The hoppers are generally filled from the floor above and are fitted with dust collectors. Feeders of this type cost $2,000 or more, depending on size and accessories.

Slight overdosage has occasionally occurred when the solution box was flooded

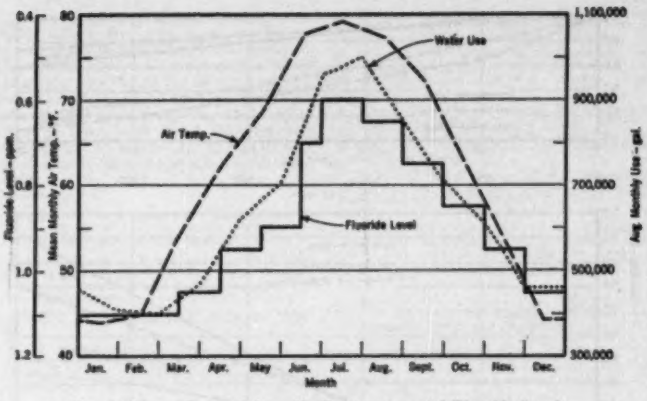

Fig. 3. Water Consumption, Air Temperature and Fluoride Level.

with fluorides. This condition results when the chemical forms an arch in the hopper. When the arch collapses, the fluorides are forced over the feeding mechanism. This disadvantage reportedly has been eliminated with the development of a locking mechanism.

Manufacturers of gravimetric feeders include: Jeffrey Manufacturing Co., Columbus, Ohio; Omega Machine Co., Providence, R.I.; and Wallace and Tiernan Co., Inc., Newark, N.J.

Small feeders are generally connected electrically with the pump motors to stop the feeder automatically when the pump stops. Manual adjustment of the rate of feed is easily made on all feeders when changes in the amount of water to be treated can be anticipated. If these changes are not predictable, feeding rates can be varied automatically, with solenoid valves actuated either by a venturi or water meter.

The mechanics of feeding fluorides (except hydrofluoric acid) are no more involved than those for other chemicals used in water purification. The major differences may be that fluorides are toxic (but so is chlorine) and that an overdosage is difficult to correct. Even with a 100 per cent overdose, however, the resultant fluoride content will not exceed approximately 2.0 ppm. This concentration will produce no perceptible ill effects, even when continued for a week. Nevertheless, the rate of application should be maintained as constant as possible and close to the dose determined as optimum for the supply in question. Valuable information can be obtained from every community using fluoridated water. The interpretation of valid data will be contingent on a history of uninterrupted use of water containing a constant, static fluoride concentration. No valid or useful conclusions can be drawn from a study where the concentration has varied considerably and intermittently.

Point of Application

The point of application of the fluoride is an important factor. Almost every water supply presents a different problem, sometimes involving a compromise between what is considered the best point of application and the best place to replenish the feeder hopper. In general, fluorides are applied most effectively at that point where the risk of losing them in a subsequent treatment is least.

Untreated supplies present the fewest problems. Fluorides can be introduced either into a reservoir (if the influent rate is known), into the well directly, or into the discharge or suction side of the pump. Feeders capable of discharging solutions against any head encountered in water supply practice are available.

In treatment plants, consideration should be given to processes which have a tendency to remove fluorides. These include lime softening in the presence of magnesium; alum or sodium aluminate coagulation; feeding of bentonitic clays; and activated-carbon treatment at low pH values. As little as 10 ppm. alum, when added to water with 1.0 ppm. fluoride, will remove about 0.1 ppm. of the fluoride. It is therefore advisable to add fluorides after these treatment steps. If settling is prolonged and efficient, and if the filters remove relatively little material, fluorides can be added before filtration. On the other hand, if the load on the filters is considerable, fluorides should be added after filtration, generally either in the line between the filters and the clear well or in the clear well itself.

Chlorine can be added anywhere in the plant or distribution system. There are no known reactions between fluorides at 1.0 ppm. in water and compounds formed in water after chlorination. Fluorides at this concentration have no bactericidal effects.

Side Effects

There are no noticeable effects of 1.0 ppm. fluoride on taste, odor, color, hardness or pH value. No untoward effects have been reported by bottlers, brewers, bakeries, laundries or chemical plants. At Charlotte, N.C., where the supply is relatively unmineralized (total solids, 43.7 ppm.; hardness, 22.8 ppm.; chlorides, 2.8 ppm.; and sulfates, 4.3 ppm.) cracking of ice blocks in ice manufacturing plants increased about 50 per cent apparently after 1.0 ppm. fluoride was added (7). This phenomenon was completely eliminated by adding the equivalent of 20 ppm. ammonium chloride to the water used for ice making. No other such experience has been reported. Colorado Springs, Colo., with a water supply very similar to Charlotte's (except that 2.8 ppm. fluoride is naturally present), has had no trouble of this kind, but, in any event, the phenomenon should be investigated.

Fluoridation will provide all or part of the fluorides needed to remove silica from boiler water. An ion-exchange process is reported to require the addition of about 1.0 ppm. fluoride for each 0.5 ppm. SiO_2 removed (8). On the other hand, if sodium silicofluoride is used for fluoridation, about 0.5 ppm. SiO_2 is formed when 1.0 ppm. fluoride is added from this source.

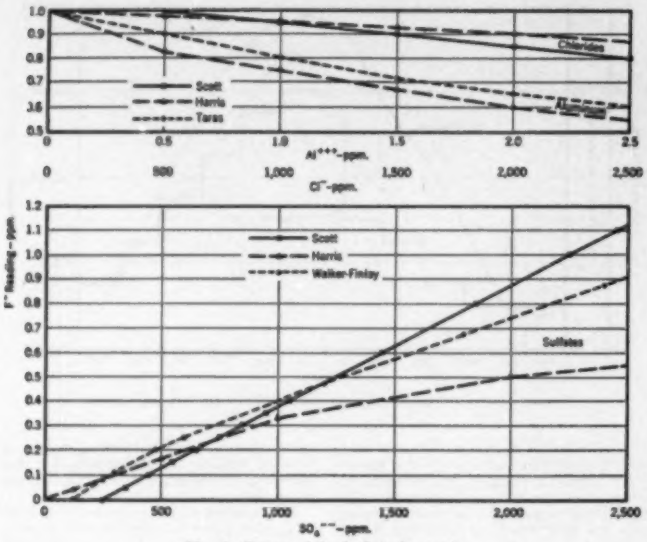

*Fig. 4. Range of Ionic Interference**

*References: Scott (10), Harris (15), Taras (14), Walker-Finlay (13).

After fluoridation has been started, the fluoride content of sewage almost immediately reaches the same concentration as in the water supply. This phenomenon has had no effects on any sewage treatment process.

Home softening units using the salt regeneration system will not remove the added fluorides.

Records and Sampling

In even the smallest installations, daily records should be kept of water treated and amounts of fluoride fed. After it has been ascertained that the optimum fluoride concentration is reaching all points in the distribution system, sampling schedules at the plant and in the system are formulated primarily to check inaccuracies of the feeder and unexplained losses in the system. Actually, if a feeder is well maintained and adjusted, its accuracy should be well within 5 per cent. This accuracy is greater than that attained by present tests for fluorides in water.

The standard test for fluoride is based on the degree of decolorization of a zirconium-alizarin lake in an acid solution (9-11). In general, this reagent is relatively unstable, the color range is narrow, the color development requires about an hour, and many other ions in water interfere with the reading. So far, the best reagent of this type is that developed by Lamar (12) in 1945. It is more stable and its color range appears to be broader than is true for other reagents. Interference with other ions is considerably reduced.

As shown in Fig. 4, interference by other ions using the present standard method (Scott-Sanchis) is considerable. In addition, a 0.10-ppm. free chlorine residual considerably decolorizes the lake, producing an apparent increase in fluorides. It has been reported that water containing 1.8 ppm. chlorine can be dechlorinated by adding one drop of 0.1*N* sodium thiosulfate per 100 ml. of sample (14). Ultraviolet rays obtained either from sunlight or lamps will also dechlorinate the fluoride sample.

If the quantities of interfering ions exceed the maximums shown in Table 3, the most accurate procedure is to distill the sample in perchloric or sulfuric acid (17). The distillate will contain all the fluorides and practically none of the interfering ions. If the excess of these ions is not too great, the sample might also be diluted with distilled water and the fluoride content of the aliquot determined in the usual way.

Setting up a series of standards—a laborious step in the fluoride determination—is no longer required in routine analysis where the accuracy desired is within 0.20 ppm. fluoride and the interference is negligible. Permanent color standards of glass or liquid are available and can be fitted into a comparator. The color gradations of the liquid standards in sealed tubes are based on the Lamar reagent; those of the glass standards, on the Scott-Sanchis reagent.

TABLE 3

Upper Limits of Ionic Interference Using Scott-Sanchis Reagent to Give Maximum Error of Approximately 0.02 ppm. Fluoride

Substance	Fluoride Reading Too Low If More Than:	Fluoride Reading Too High If More Than:
	ppm.	
Chlorides	500 (2,500—Lamar)	
Aluminum*	0.10	
Alkalinity (as $CaCO_3$)	150 (400—Lamar)	
Sulfates		150 (1,000—Lamar)
Iron		0.5
Phosphates (PO_4)†		1.6-3.3
Phosphates (PO_3)6†		0.3
Chlorine		0.02‡
Manganese		0.02‡

*Ref. 15.
†Ref. 16.
‡Ref. 14.

Safety Measures

No skeletal changes, except the mildest forms of dental fluorosis, have ever been observed in individuals who have continually used water containing 1.0 ppm. fluoride. Damage to the bones (osteosclerosis) has occurred after 2½ years' continuous exposure to cryolite and phosphate rock dust, whereby probably 15-25 mg. fluoride per day was inhaled (18). Industrial hygienists have set a threshold limit of 2.5 mg. fluoride per cubic meter of air. Present practice in water treatment plants is to obtain equipment permitting the fluoride feeder hopper to be filled no oftener than once a day. If reasonable care is used in handling the fluorides so as to produce the least dust, little danger to the operators is involved.† Actually, the greatest hazard occurs in the larger plants, where the fluorides are dumped from a barrel into a hopper opening which is at floor level. Occasionally the fluoride arches in the barrel and then, suddenly emptying, throws a cloud of dust into the air. In such installations a dust exhaust system should be made part of the hopper equipment.

Hopper exhaust systems usually involve a series of socks hung in a steel enclosure opening into the top of the hopper, adjacent to the feeding door. A motor-driven fan draws air from the hopper through the socks and exhausts to the atmosphere. At Oshkosh, Wis., the suction is derived from an aspirator type water eductor. The sodium silicofluoride dust entrained in the water is carried to a sedimentation basin.

When filling hoppers, the operators should wear masks. Those of the type BM2101,* equipped with a filter designed for dusts (BM2133),* are satisfactory.

In smaller plants where the hopper or solution tank is replenished by means of a scoop, little or no dust is generated if the fluorides are handled carefully. Here, too, however, a mask should be worn. Rubber gloves should also be worn and the hands washed after each filling. Spilled fluorides should be wet-mopped and discarded.

The crystalline sodium fluoride, now available in a larger particle size (20-40 mesh), should reduce the dust problem to a minimum, because a very low percentage of this material contains particles small enough to form dust.

Initiation of Fluoridation

Many fluoridation projects have been started as a result of the interest created by local dental and medical societies. Many of these groups have presented their evaluations of reports containing factual and convincing proof of the benefits demonstrated at places where fluorides are naturally present and, lately, where they have been artificially added. The local councils, with or without a public hearing, but always with public support, have then authorized (sometimes by ordinance) the local water departments to proceed.—

A.W.W.A. official policy as published in the JOURNAL (19) states (Sec. 4) that:

The operating management of a water supply utility should begin the addition of fluoride in the water supply only after:

4.1. The governing body of the municipality has authorized fluoridation by ordinance, and the local and state health authorities have approved the addition of fluoride and have: [1] established reasonable maximum and minimum limits of fluoride, stated in parts per million, to be maintained in the water supply; [2] approved the type of chemical feeding equipment to be installed and used; [3] approved the installation of equipment, plant layout and methods of handling the fluoride com-

*U.S. Bureau of Mines designation.

†See Water & Sewage Works, Vol. 98, p. 335 (1950).

pound to assure the safety of employees; and [4] approved the method of analysis and control to be used in determining the fluoride content of the water before and after the addition of fluoride.

4.2. The state or provincial public utility commission has released, when required, any necessary orders—for example, a method by which the utility will be reimbursed for the expense of fluoridation.

4.3. The legal counsel of the water department or company has made a finding that all necessary authorization has been given to the water utility so that legal liability for damages will be limited to negligence.

4.4. The board of directors or similar governing body of the utility has, by resolution, instructed its proper operating officers and employees to add fluoride as specifically authorized by the controlling health and municipal authorities.)

Permission and advice are always obtained from the state health department, and, where applicable, an opinion on liability is obtained from the state attorney general. These opinions have always reiterated the water department's liability for damage resulting from negligence. Money for fluoridation has come from the general fund or from health or water department appropriations, but usually from the health department.

Summary

Before adding fluorides to the water supply, these points should be observed:

1. There is a possibility, particularly in the southern latitudes of the United States, that too much fluoride may be added, with the result that an undesirable degree of fluorsis may develop.
2. Operators should be trained to recognize the toxicity of fluorides and to handle them safely.
3. Dosages should be made as accurate and as constant as possible.
4. Complete records should be kept of the amounts of water treated and the quantities of fluoride used.
5. Daily fluoride tests of samples from the plant and distribution system should be made and recorded.

In the light of evidence obtained from places which have long used water containing the optimum fluoride concentration, and, lately, from those communities which are adding fluorides, it can be recommended that plans approved by the state health department for fluoridating the water supply should be formulated. Every delay deprives children of a substantial health benefit which may be obtained at a negligible cost.

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EXPANSION CHART*

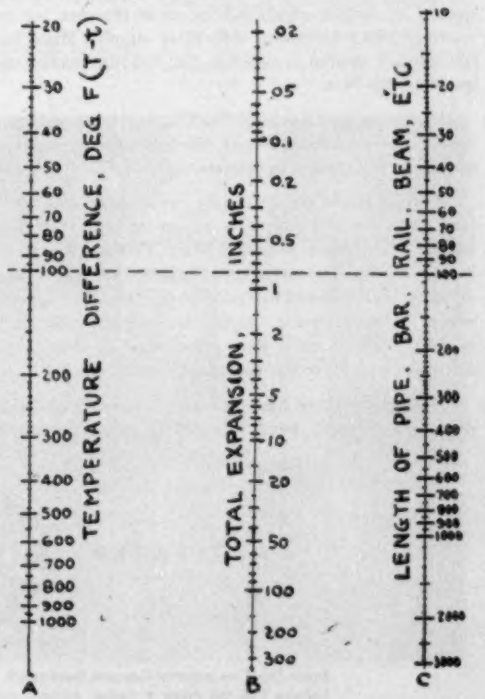
This chart is useful for determining the expansion in pipes, rods, tubes, beams, shafts, columns, struts, etc., for any ordinary temperature difference. It makes "longhand figuring" unnecessary. Simply lay a straight-edge across the chart once or stretch a fine black thread across, as indicated by the dotted line, and the problem is solved.

Example: If a certain pipe line 100 ft. long is subjected to a temperature variation of 100 deg. F., what will be the total expansion in inches?

Simply connect the 100 deg. *temperature difference*, column A, with the 100 ft. length, column C. The intersection with column B gives the answer as 0.8 in. That is all there is to it.

The chart can also be used for determining the allowable temperature difference where a definite amount of space is available for expansion and contraction. Thus if the length of the pipe is 100 ft. and the allowable expansion is 0.8 in. the same line would show that a temperature difference of 100 deg F. would be the limiting amount.

*Contributed by W. F. Schaphorst, M.E., Newark, N.J.



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AQUA NUCHAR ACTIVATED CARBON

Aqua Nuchar is a quality of activated carbon specifically produced for water purification. Its characteristic is a high adsorptive power for those foreign molecules in water which give rise to objectionable odors. Aqua Nuchar offers the quickest, lowest-cost way to eliminate odors and prevent their recurrence. It is estimated that the year 'round use of Aqua Nuchar Activated Carbon costs on an average less than two cents per capita per year.

With the increase in use of activated carbon in water treatment, competitive carbons and competitive treatments entered the field. Thus it became necessary to develop tests and suitable specifications whereby municipalities would be able to select the activated carbon most suitable for their individual needs.

Development of the Theshold Odor Test supplied the means of measuring odor intensities in water and by means of this test it is possible to determine that quality of carbon which will be most effective for removing odors from the individual supply. Municipal officials are invited to write us for full information regarding this test.

Members of our Research Staff have carried on evaluation tests, comparing Aqua Nuchar with competitive materials for ability to remove odors.

Odors in water are frequently erroneously characterized as tastes. Psychologists recognize four taste sensations; salt, sweet, sour and bitter. Perhaps the greatest cause of odor in water supplies is due to Algae. Odor is occasionally caused by trade wastes, resulting in very severe odor epidemic. Aqua Nuchar removes these odorous compounds in water, thus enabling delivery of a palatable water to the consumer at all times.

Even where there has been no consumer complaint, many plants apply small dosages of Aqua Nuchar in order to prevent a sudden taste or odor condition from getting out of hand. Thus, when tastes and odors develop in a raw water supply, it is only necessary to apply somewhat increased dosages of Aqua Nuchar to control the condition.

AQUA NUCHAR HAS THESE SPECIAL QUALITIES: It disperses more quickly throughout the entire body of water and remains in suspension a longer period of time. Thus the carbon particles have a greater opportunity to contact taste and odor bodies in the water in order to accomplish their REMOVAL BY ADSORPTION.

It is common practice in the design of new plants to provide for activated carbon treatment of the water. Application of Aqua Nuchar Activated Carbon is advisable not only in all water supplies where tastes and odors may be present, but also in water where tastes and odors become apparent after chlorination. It is a wise precaution under all circumstances.

During floods and high water, odorous compounds may be flushed down to your water intake. Therefore at such times Theshold Odor Tests should be run regularly and you should be prepared with an adequate supply of Aqua Nuchar.

A typical analysis of Aqua Nuchar, which has been used in nearly 1,200 plants the country over, shows:

FINENESS: Through:	
100 mesh screen	100%
200 mesh screen	97%
325 mesh screen	95%
WEIGHT PER CUBIC FOOT:	
Louse	15 pounds
Packed	19 pounds

Warehouse and factory stocks are maintained at strategic points throughout the country so that rush deliveries can usually be made within twenty-four hours or less by local express.

ACTIVATED NUCHAR **CARBON**

Snow Top Precipitated Calcium Carbonate • Liqro Crude Tall Oil • Indusoil Distilled Tall Oil
Tallene Tall Oil Pitch • Tallex Abietic Acid • Polycel Cellulose Fibers • Indulin (Lignin)

CONTROLLING TASTE AND ODOR WITH ACTIVATED CARBON*

By E. A. SIGWORTH

Water Purification Division, Ind. Chem. Sales Div., West Virginia Pulp & Paper Co., New York City.

THE importance of palatability of water is being recognized more and more by the water works profession. Great strides have been made in removing color and turbidity and destroying harmful bacteria, so that today most public water supplies are clear and sparkling and safe from the health point of view. Great strides have also been made in improvement of palatability of water since the first application of activated carbon by George Spalding at the New Milford, N.J., plant of the Hackensack Water Co. in 1930. However, many instances still exist where unpalatable water is still being delivered to consumers, sometimes almost continuously and at other times for very short periods. Unfortunately, the consuming public will long remember unpalatable water even though it may be for only one day out of the year. Certainly those individuals desiring to develop good public relations must strive to deliver palatable water consistently.

It must also be borne in mind that the public of today is much more widely traveled than that of a generation ago. Thus consumers have an opportunity to taste water in other localities and can make comparisons which can sometimes react unfavorably to the local supply. Health officials realize that it is essential to deliver water which is perfectly safe from the bacteriological point of view. They also recognize that an unpalatable water can also constitute a health menace by driving consumers to more palatable but perhaps less safe supplies. Therefore, in an indirect way, it is recognized that an unpalatable water can be a possible contributing factor to the cause of illness within a community. With the various available methods for taste and odor control, greater emphasis would seem justified in attempting to produce palatable water.

Causes of Odors

The three main causes of odors are: Algae growths within the water supply, decaying vegetation, and trade wastes. Of these algae are the most prevalent causes of odors as indicated by a survey conducted some years ago. Although there are many varieties of algae, the ones most likely to cause taste and odors fall within approximately 25 to 30 types. These algae, during their life cycle, give off compounds which result in characteristic odors in the water. In some cases, simply by smelling the water it is possible to decide the type of algae which may be causing the odor.

Decaying vegetation usually results in an odor which may be characterized as grassy, musty, swampy, or moldy. These odors result from decomposition of vegetable matter such as grass, under-water weeds, leaves, etc.

Although trade wastes may be the least frequent offender, they can also create the most difficult condition to correct. In other words, odor concentrations may reach extremely high proportions necessitating the entire ingenuity of the operator to reduce them to a palatable level.

Wherever possible, every effort should be made to prevent odors from reaching the water supply. Therefore, preventive measures should be adopted such as copper sulfate treatment for algae control, dredging or damming off shallow areas, and cooperation with plants on the watershed area in order to attempt to reduce trade waste pollution.

Evaluation of Odors

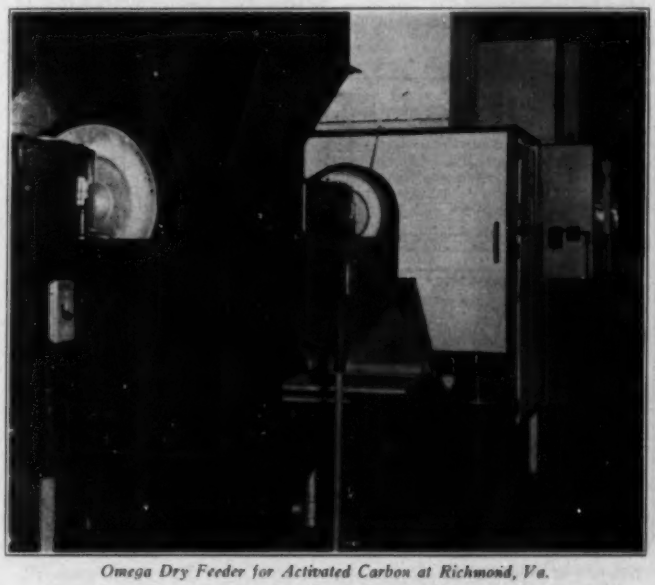
The development of the "Threshold Odor Test" has provided the industry with a satisfactory means for odor evaluation. This test involves diluting a sample of water with varying amounts of odor-free water until the point is reached where odors are just detectable and further dilutions show no detectable odor. By this method, odor concentrations can be assigned definite numbers directly proportional to odor concentration. For example, an odor number of 20 would be 10 times as strong as an odor number value of 28. Thus this test provides the water works operator with a means of determining when it is necessary to institute corrective methods for odor control.

It is also possible with this test to measure the relative efficiency of various treatment methods and chemicals, to determine when the water is palatable and when it is not, and to determine the best point of application for corrective treatment. It has been estimated that a threshold odor of 5 will normally constitute a palatable level for the average consumer. This value assumes an average observer and is based on odor evaluations being conducted on heated samples (60°C) which gives higher color values than those determined on cold samples. If the operator is super-sensitive to odors, the level of palatability might have to be increased, and vice versa.

Activated Carbon

Activated carbon, as most frequently used in water treatment, is a very fine black powder. Activated carbon acts by the phenomenon called *adsorption* which should not be confused with absorption. The concentration of certain specific substances at exposed surfaces is known as adsorption. On the other hand, the picking up of water by a sponge is known as absorption. If a container is filled with a dye solution and a sponge inserted in the solution and withdrawn, absorption takes place. The sponge takes up both water and dye without any change in concentration. In other words, it would be the same as pouring some of the dye solution out of the container. On the other hand, if a piece of clean cloth is dipped into the dye solution, there will be a greater proportion of the dye taken up on the cloth. If successive pieces of cloth are dipped into the dye solution, it will be possible to note a distinct lightening of the color of the dye solution. This phenomenon is known as adsorption.

If activated carbon is added to a dye solution it is frequently possible to obtain complete removal of the dye by adsorption. This phenomenon is explained by exposure of clean surfaces where impurities can concentrate and thus be removed from solution. This is one of the reasons that the carbon used in water purification is such a fine powder. Extremely small particles result in a greater degree of surface exposure, and the porous structure of activated carbon adds to this great amount of surface. Extremely clean surfaces may be considered as the really active patches on which maximum adsorption takes place. So great is the surface exposure obtainable with activated carbon that it has been calculated that one



Omega Dry Feeder for Activated Carbon at Richmond, Va.

*A complete revision and modernization of an article on Taste and Odor Control in the Ref. and Data issue of Wat. & Sew. Wks. in July, 1947.

cubic inch of activated carbon can account for internal and external surface of approximately 10,000 square yards. It has also been estimated that one gram of activated carbon (about one normal heaping teaspoonful) will contain approximately 120 billion particles.

The fineness of the carbon particles, coupled with their porous character, gives another advantage in water treatment by permitting the carbon particles to disperse widely throughout the water and remain suspended for long periods of time. This dispersion and suspendability permits greater opportunity for odorous substances to come in contact with the active surfaces which then attract and hold the impurities on the carbon surface. As the carbon particles settle out or are removed by filtration, the odorous compounds are also removed.

It will thus be realized that adsorption of taste and odors with activated carbon actually removes the offender from the water. Therefore, it does not change the odor to some less offending compound nor does it mask objectionable odors.

Feeding Activated Carbon

Activated carbon is insoluble in water and, since it is rather difficult to wet, must be used as a slurry. It can be fed by dry-feed machines which proportion the carbon while in the dry condition, after which the carbon is wet in the solution box and subsequently applied as a carbon slurry. The predominant method of applying carbon is through dry feed machines many of which are available on the market today.

Occasionally some difficulties are encountered with dry-feed machines so that the following suggestions are worthy of consideration. The feeding hopper should be so designed that powdered carbon will not bridge in the hopper thus preventing carbon from reaching the feeding mechanism. The capacity of the dry-feed machine should be more than ample to take care of the most severe odor condition likely to develop within the water treatment plant. The solution box should be designed so as to wet the carbon completely, and the water ejector should be of ample size and capacity to carry the carbon slurry away, even when the machine is operating at maximum capacity.

Some few plants still utilize solution methods of feeding carbon and there is a possibility that this method of carbon handling may increase in the future particularly where large quantities of carbon are involved. Several years ago the Metropolitan Water District of Los Angeles installed a tank for the purpose of storing activated carbon in slurry form. More recently the City of Chicago has done extensive work of a similar nature and has gone a step further.

In the case of the City of Chicago, arrangements were made whereby carbon would be received in bulk hopper cars from which the bulk carbon should be dumped directly into the slurry storage tanks. This method of carbon storage has many advantages such as reducing the dusting effect of carbon throughout the plant, reducing labor costs of handling bags of carbon, making available carbon in large concentrations ready to apply at a moment's notice, and assuring that the carbon particles are thoroughly wet and ready to go into immediate action when applied to the water supply. It is expected in the future that this method of handling carbon will receive wider acceptance but it is desirable to caution anyone interested that extreme care must be utilized in design of equipment, type of metals to be used, type of pumps, etc. (See "Progress in Carbon Slurry Handling at Chicago, Ill.," by John R. Baylis—March 1950 issue, *Taste and Odor Control Journal*.)

Points of Application

In a water treatment plant carbon should be applied at a point prior to filtration or, if no filters are available, prior to coagulation and settling. Thus, in the normal water treatment plant, carbon can be applied to the raw water, mixing basin, settling basin, or directly to the filters.

Where odors develop suddenly, they may get through the plant before being detected, and the carbon should be applied either on top of the filter or to the filter influent. In this manner, carbon is applied to that water which will first reach the consumer. This point of application is most frequently reported to give the greatest efficiency from the carbon for removal of tastes and odors. In many cases, surprisingly low carbon dosages are reported to give exceptionally good results in removing tastes and odors from water supplies by application to the filters. Where odors are usually at low concentration or appear at infrequent intervals, this point of application is usually recommended.

If high dosages of carbon are necessary to correct an odor condition, application of carbon to the filters may result in high loss of head, and possibly in the passage of carbon through the filter beds. Therefore, where carbon is used continuously, it is recommended that the point of application be moved so that it is applied at a point appreciably ahead of filtration. Also, where dosages in excess of 50 pounds per million gallons (6 ppm.) are necessary, carbon should not usually be applied to the filters. Under such circumstances, application is recommended to the mixing basin or to the raw water. In some cases, carbon has been applied part way through the settling basin but caution should be taken to insure that under such circumstances the carbon will have an opportunity to disperse rather uniformly throughout the entire body of water to be treated.

Use of other chemicals can also influence the best point for carbon application. For example, if lime or soda ash is utilized for pH adjustment, it may be desirable to apply carbon prior to these chemicals by as much as 15 to 20 minutes. This is particularly true if the pH of water is raised above the value of 8.5. In many cases alkaline substances are formed which may be less readily adsorbed by activated carbon. Phenol is a specific example, being less readily removed from water by carbon at high pH values.

It is never desirable to apply carbon and chlorine at the same point. Carbon has a tendency to adsorb chlorine just as it adsorbs odorous compounds. Thus some of the chlorine will be taken up by the carbon, thus reducing its potential for disinfecting the water. Also the efficiency of carbon for adsorption of odorous compounds may be slightly decreased. Their points of application should be separated by at least 15 minutes and preferably more.

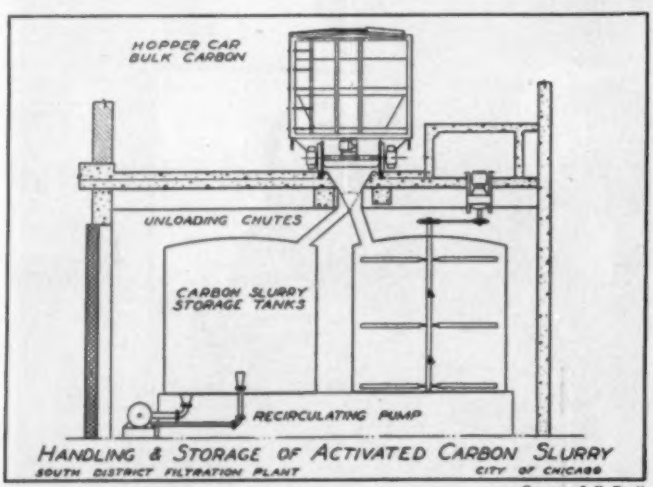
Just which chemical should precede the other will depend to some extent on existing conditions. If chlorine reacts with the odorous compound and makes it more difficult to remove by carbon, then carbon application should precede that of chlorine. Naturally the reverse is true if the chlorinated odorous compound is more readily adsorbed by carbon.

Based on experiences thus far, chlorine is more likely to make the odor compounds more difficult to remove with carbon. Therefore, as a general rule, it would be best that carbon application precede that of chlorine. If pre-chlorination is practiced and the chlorine is applied to the mixing basin, it is suggested that carbon be applied to the raw water as far in advance of reaching the mixing basin as possible (preferably 15 minutes or longer). By following this practice, carbon will have an opportunity to adsorb the odorous compounds before the chlorine has an opportunity to react. It may also be found that the carbon will adsorb other organic compounds which would normally constitute a chlorine demand. Thus, pre-treatment with carbon may possibly result in a reduction of the chlorine demand of the water.

Determining the Carbon Dosage

In many cases, particularly where suitable laboratory facilities are not available, the carbon dosage is determined by "hit-and-miss" methods in actual plant practice. This can frequently result in over or under dosage. More scientific methods are recommended.

In the laboratory, the use of the "Threshold Odor Test" is very successfully used in



Courtesy J. R. Baylis

Diagram of Handling and Storage of Activated Carbon Slurry at Chicago, Ill.

determining the carbon dosage. Naturally, it is necessary first to know to what extent the odors must be removed in order that a palatable water can be delivered. For this purpose, a taste and odor panel is recommended consisting of at least four individuals. Samples of raw water should be chlorinated sufficiently to make the water safe for testing purposes. This water can then be filtered and diluted with varying amounts of odor-free water for tasting purposes. That sample having the least dilution of odor-free water and which is pronounced acceptable by all four tasters can usually be considered as the palatable limit. A threshold odor test can then be conducted on this sample of water and the threshold number will represent the value which must be reached in actual practice.

Having determined the palatable level, samples of water should then be treated with varying amounts of activated carbon. A sample should be collected at a point just prior to any carbon application. If carbon is not being used, a sample of raw water can be collected. To various samples, not to exceed four in number, should be added different dosages of activated carbon. For example, 2, 4, 8, and 16 ppm. If odor concentration is considered to be rather high, it would be desirable to use higher carbon dosages than suggested above.

After addition of the proper carbon dosage, each sample should be treated exactly the same as the existing treatment in the purification plant; this will include alum, lime, chlorine, etc. Individual contact times should parallel as closely as possible actual detention times in the plant. Then samples are finally filtered, preferably through glass wool as the filter medium. This glass wool and all receptacles should be thoroughly rinsed with odor-free water to assure that extraneous odors are not added to any of the samples.

Finally, these treated samples, and also a sample of the raw water, should be evaluated for threshold odor number in accordance with the procedure in "Standard Methods." Results obtained should be plotted on arithmetic graph paper and the curve drawn as accurately as possible to conform to the plotted points. From this curve it should be possible to determine the carbon dosage necessary to produce the threshold number which has previously been determined as acceptable for a palatable water.

In transposing these results to actual plant practice, it should be borne in mind that activated carbon accomplishes better results in plant practice than in small scale laboratory tests. Therefore, it is desirable that the dosage determined in the laboratory should be cut in half for the first plant test. Usually it will be found that half the laboratory dosage will give the desired results in plant practice. Some exceptions to this generalization have been encountered so that the final plant dosage may have to be increased or decreased to give optimum results. For example, if it is found that a laboratory dosage of 12 ppm. of activated carbon is necessary to reach the palatable level, only 6 ppm. carbon should be employed in the first plant scale test. Based on results obtained in the plant, it may be necessary to revise the carbon dosage to as low as 4 ppm. or perhaps as high as 8 or 10 ppm. Such relations, once developed between laboratory and plant results, can usually be utilized as a base in any subsequent tests.

Unfortunately, it is not possible to set any hard and fast rule as to the amount of carbon necessary, even though the threshold number of the raw water is known. For example, in some plants it has been found that one part per million of carbon is necessary for each threshold unit in order to accomplish palatability. Yet, in other parts of the country, this ratio may be one part of carbon for every three or four threshold odor units.

The type of odorous compound is also a contributing factor to this ratio. Therefore, if the type of odor changes suddenly, it is desirable to conduct another evaluation in order to determine the necessary carbon dosage. The reason for this is that some compounds may be easier or more difficult to adsorb by carbon. Also, it should be borne in mind that as odor intensities increase carbon dosages may have to be greatly increased. In other words, if the odor concentration suddenly doubles, it may be necessary to use three times as much carbon in order to remove the objectionable odors. In any case, laboratory tests can constitute a very valuable guide in determining the optimum carbon dosage for plant scale use, always bearing in mind the relation between laboratory and plant results.

In actual plant operation carbon dosages used will vary from as low as two pounds per million gallons to as high as one thousand pounds per million gallons. Extremely high dosages such as 500 pounds per million gallons or more are rather rare and, fortunately, are usually of only very short duration. Although costs of treatment during these short periods of time would seem to be enormous, the average cost over the year is usually found to be very reasonable. If the total carbon costs are calculated on a per capita per year basis, it will be found that the actual cost is very nominal.

Reservoir Application

Difficulties with unpalatable water unfortunately do not limit themselves to systems where water purification facilities exist. Unfiltered reservoir supplies are perhaps even more likely to have odor difficulties, particularly of the algae type, because the water must be clear in order to be suitable for delivery to the public. Since algae thrive more particularly in clear waters, impounded supplies must always face this problem.

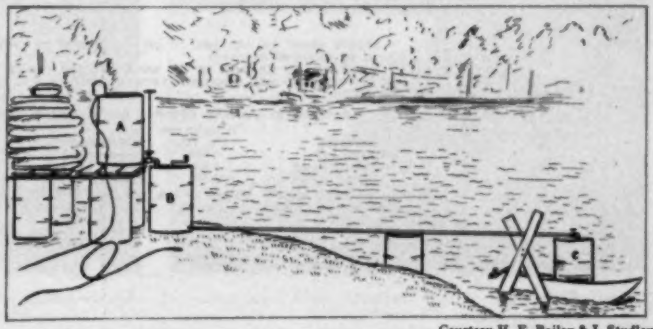
Since activated carbon is a fine black powder which will give a black turbidity to water, it is desirable that treatment be conducted so that little or no carbon reaches the distribution system. The general practice is to treat reservoirs with activated carbon so that no carbon is applied at any point near the reservoir intake. Thus the carbon particles have an opportunity to settle from the water and any small amount that might get into the distribution system would not be noticeable to the consumer. In some instances, carbon has been applied to reservoirs without regard to the proximity of the intake. Under these circumstances the dosage of carbon is usually kept at a minimum of say approximately 1 ppm. so that the small amount of carbon that would get through would not be sufficient to constitute consumer complaints. If the first treatment is insufficient to produce palatable water, further treatments can be made at weekly intervals until the difficulty is corrected and without any serious objections from the consumers.

In the actual application of carbon, the usual practice is to apply it in slurry form. This slurry form of carbon is applied to the reservoir on much the same principle as with copper sulfate. However, in the case of carbon, higher dosages should be applied in the deeper areas so that the carbon concentration in the water is distributed as uniformly as possible.

Preparing the carbon slurry can constitute a problem unless proper equipment is available. An excellent method was worked out by Howard E. Bailey and James B. Studley for applying carbon to a reservoir at Pembroke, Mass. (See "Activated Carbon Treatment of An Open Reservoir," *Water & Sewage Works*, p. 219, June, 1947.) In this particular case, arrangements were made to prepare a carbon slurry on the shore of the pond. This slurry was then piped to the water's edge where the boat could come in for charging. A drum in the boat was used to hold the carbon slurry from which it was discharged to the reservoir. Complete details are described in the above mentioned article.

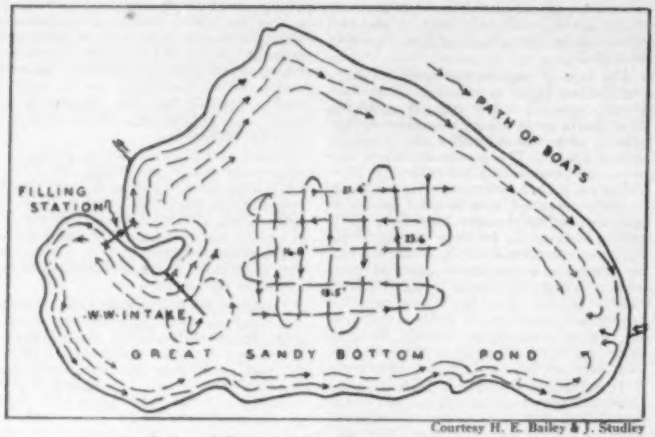
Another procedure was utilized by Fred Luthy at Orange, New Jersey. A boat was equipped with a gasoline motor and pump, and a 50 gallon steel drum for the carbon slurry. Bags of carbon were loaded aboard the boat for wetting. The pump served to supply water to the drum where the carbon slurry was prepared, and the pump also served to force the carbon slurry under pressure through a hose for distribution to the surface of the reservoir. Complete details of this arrangement are included in an article entitled "Powdered Activated Carbon Application to Orange Reservoir"—September 1950 issue, *Taste and Odor Control Journal*.

Based on the small concentrations of carbon utilized thus far in reservoir applications with successful results, there seems reason to believe that this method of treatment constitutes a very efficient procedure. Generally speaking, dosages used are in the very low ranges normally used in water treatment plants. Yet, the production of a palatable water from a very severe odor condition has been the result very consistently. There is also the possibility that the carbon which settles out at the bottom of the reservoir can still accomplish beneficial results. This carbon will still have some



Courtesy H. E. Bailey & J. Studley

Sketch Showing Arrangement for Carbon Treatment Plant at Open Reservoir



Courtesy H. E. Bailey & J. Studley

Course of Boats for Open Reservoir Treatment
(Great Sandy Bottom Pond, Rockland, Mass.—108 Acres, 300 mil. gal.)

reserve capacity for odor adsorption, and it may act toward stabilizing any decomposition odors which might normally develop at the reservoir bottom.

Blackout of Algae

In addition to foods normally present in water, algae require sunlight and suitable temperatures for propagation. The fact that activated carbon gives a dark appearance to water was considered as a possibility for eliminating the sunlight which is considered one of the essentials for algae growths. The first application for this purpose is credited to the late William P. Bailey at Council Bluffs, Iowa. In the application of activated carbon for this purpose, the carbon is thoroughly wet and applied as a slurry to the entire surface of the body of water to be treated. For successful results, application is made once or twice each day during periods favorable to algae growths. Thus application is usually limited to the summer months and also only to days of prolonged sunlight. Naturally, during cloudy days, carbon application is not necessary.

It remained for Hartung and Lischer of the St. Louis County Water Department, St. Louis, Missouri, to determine the necessary carbon dosage to treat a particular water surface. Based on their studies, it was found that a dosage of approximately a quarter of a pound of carbon would successfully black out a water surface of 1,000 square feet. Thus it must be realized that the dosage necessary for carbon blackout is usually far below that necessary for accomplishing taste and odor control. However, if carbon is necessary for correction of odors, the amount used for algae blackout would automatically reduce the quantity of carbon necessary for eliminating odor conditions. Studies in the field have shown activated carbon to be the most universally successful answer to taste and odor problems. Some reported failures have been due to improper point of application or an attempt to accomplish results with too small a dosage. It is safe to state that almost all odors can be reduced to a palatable level with activated carbon if a sufficient quantity is used at the proper point of application.

CONCRETE

Quantities of Materials for One Cu. Yd. Rammed Concrete Based on Barrel of 3.8 Cu. Ft.

Proportions	Using ¾-in. Gravel and Under, Sand Screened Out: Cement Barrels	Sand Cu. Yds.	Gravel Cu. Yds.	Using 1-in Stone and Under, Dust Screened Out: Cement Barrels	Sand Cu. Yds.	Stone Cu. Yds.
1:1½:3	1.71	0.39	0.78	1.85	0.42	0.84
1:2 :4	1.34	0.41	0.81	1.46	0.44	0.89
1:2 :5	1.17	0.36	0.89	1.27	0.39	0.97
1:2½:5	1.10	0.42	0.83	1.19	0.46	0.91
1:3 :5	1.03	0.47	0.78	1.11	0.51	0.85
1:3 :6	0.92	0.42	0.84	1.01	0.46	0.92
1:3½:6	0.88	0.46	0.80	0.95	0.50	0.87
1:3 :7	0.84	0.38	0.89	0.91	0.42	0.97
1:3½:7	0.80	0.42	0.85	0.87	0.47	0.93
1:4 :7	0.77	0.47	0.81	0.83	0.51	0.89
1:4 :8	0.71	0.43	0.86	0.77	0.47	0.93

Proportions	Using 2½-in. Stone, Most Small Stone Screened Out: Cement Barrels	Sand Cu. Yds.	Stone Cu. Yds.	Using 2½-in. Stone and Under, Dust Screened Out: Cement Barrels	Sand Cu. Yds.	Stone Cu. Yds.
1:1½:3	1.96	0.45	0.89	1.90	0.43	0.87
1:2 :4	1.53	0.47	0.93	1.48	0.45	0.90
1:2 :5	1.33	0.39	1.03	1.29	0.38	0.98
1:2½:5	1.26	0.48	0.96	1.21	0.46	0.91
1:3 :5	1.17	0.54	0.89	1.14	0.53	0.87
1:3 :6	1.06	0.48	0.97	1.02	0.47	0.93
1:3½:6	1.00	0.53	0.92	0.97	0.51	0.89
1:3 :7	0.94	0.42	1.05	0.92	0.42	0.98
1:3½:7	0.91	0.49	0.98	0.89	0.47	0.95
1:4 :7	0.87	0.53	0.93	0.84	0.51	0.90
1:4 :8	0.81	0.49	0.98	0.78	0.48	0.93

Figure about 1¼ cu. yds. of pit run gravel to make one cubic yard of rammed concrete.

Variations in fineness of the sand and the compacting quality of the concrete may affect the above quantities 5 to 10% in either direction.

Weights of Cement, Crushed Stone, Gravel and Sand

Material	Weight per Cu. Yd.	Material	Weight per Cu. Yd.
Bank sand	2,500	Screenings	2,500
Torpedo sand	3,000	Gravel	3,000
Crushed stone	2,500	Roofing Gravel	3,000

Portland cement weighs 94 lbs. per bag, or 376 lbs. per bbl. One bag is equivalent to 1 cu. ft.

CHEMICAL WEED KILLERS

By MARTIN E. FLENTJE
Research Engineer, American Water Works Co., Inc., New York, N.Y.

WEED problems of the water works industry may be divided into three categories. The first is weed growths in the water itself, either (a) projecting above the water, or (b) growing entirely underneath the water surface. For these growths no solution is offered. Second, weeds growing on reservoir banks—either on banks sloping sharply toward the water or those on more level banks immediately adjacent to the water. Third, undesirable weeds and growths in other locations, as for example, on rights of way, driveways, walkways, parking lots, recreational areas, etc.

Any chemical used for control of the weeds falling into the first two divisions above must be of such character that no harm will be done to the water, through the use of the chemical, that would prevent its use for drinking and culinary purposes. If the area in question is on the immediate watershed of a public water supply, this same restriction will, of course, also apply to control of weeds in the third category. This restriction removes from consideration such effective chemical weed killers as the arsenical compounds, certain organic compounds (sulfamates), petroleum oils, and possibly certain chlorinated organic materials that are dangerous to use, or others which might cause taste and odor. This short report will deal with those weed killing agents that have come to our attention or have been used. Several have been experimented with and others appear to be useable in public water supply locations.

The chemicals that offer promise (with safety) appear to be:

2,4-D Compounds

The 2,4-D compounds (now widely used on lawns and on farms). Chemical weed killers are classed as either (1) selective, or (2) non-selective. The 2,4-D chemicals under usual dosages are selective "agents," which means that they will kill certain weeds and plants and not others (a "non-selective" agent will kill all plant growth). The various "2,4-D" weed killing compounds are formulations of 2,4-Dichlorophenoxyacetic acid. Among the compounds available are the sodium salt of 2,4-D acid; a compound known as "2,4-D,amine" and containing triethanolamine salt of 2,4-D acid; and an ester form of the acid called "2,4-D,Ester," "Esteron," etc.

The 2,4-D weed killers are particularly effective against broad-leafed plants, killing off the top growth and in the case of certain weeds killing off a high percentage of the roots also. The 2,4-D weed killers are non-poisonous to humans and animals. They are neither combustible nor inflammable and will not corrode equipment. They only temporarily affect soil—the time varies from approximately 2 weeks to 4 months depending on condition of soil, rainfall, etc.

Near Washington, D. C., and in Louisiana 2,4-D chemicals have been successfully used to control weeds growing in water (not, however, used for water supply). Three applications were required. An experiment with the ester form of 2,4-D is being carried out by the writer's organization this summer at Bristol, R. I. The weeds in this location are largely the broad-leafed type known as "Ponderose."

Chlorates

It is claimed that there are no other chemicals as effective for weed control as the chlorates. Chlorates are "non-selective" and kill all kinds of weeds and grasses. They are quick acting and, according to manufacturers, destroy both roots and vegetation. Sodium chlorate, the most used of the chlorates, is safe for use in a water supply. Users must, however, take *extreme caution* in handling and applying it due to the fire hazard involved. One product contains calcium chloride which greatly minimizes the danger of fire when sodium chlorate is used. Sodium chlorate is also sometimes mixed with borax to get long-term weed control.

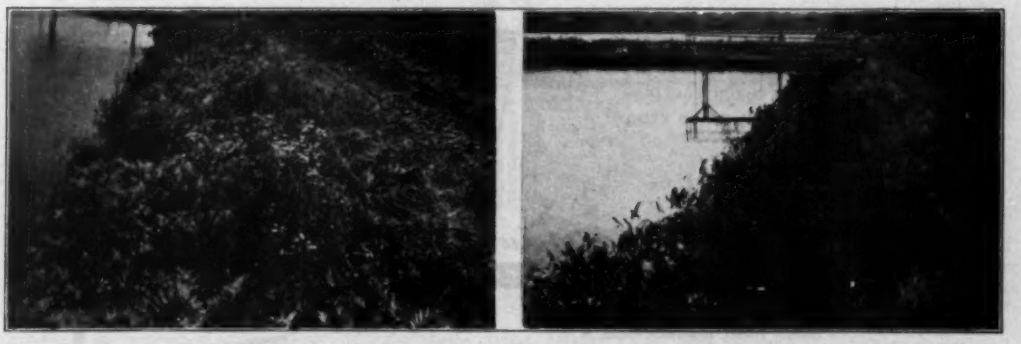
Borax Compounds and "Borascu"

One of the so-called minor elements necessary for plant growth is boron. Large quantities of boron, however, result in the death of most plants. This fact is made use of in killing weeds with boron compounds. One such product is known as "Borascu." This material is described by the Pacific Coast Borax Co. as a concentrated borate ore, from which borax in the refined form is obtained. "Borascu" is easily applied, is non-combustible, non-corrosive and safe to handle, but can only be used where it is desired to free an area of *all* vegetation. Poison ivy seems especially susceptible to "Borascu." Under favorable conditions, "Borascu" functions as a soil sterilant and when a sufficient quantity has been applied (either originally or in a retreatment) the average weed growth will be under control until the normal leaching has taken the boron content below the effective layer of top soil in which the roots are growing.

Good results have been obtained with this chemical on a stone-faced (rip-rapped) sloping reservoir bank at Summit, New Jersey, following experimental application in 1948, in which 90% control was achieved with but one application—(see pictures).

The rate of application of 15 pounds per 100 square feet of area was somewhat higher than proposed by the producers, but was employed because of the advanced stage of growth and the sloping creviced surfaced to be treated. The usual application advocated is 10 lbs. per 100 sq. ft., and as little as one half this rate is said to be sufficient to kill poison ivy.

Chemical weed killers can be applied at almost any time, but are generally most effective on young plants. The materials mentioned above are relatively inexpensive and seem to warrant further consideration and test in water-supply areas.



Weed Growth on the Rip-Rapped Banks of the Commonwealth Water Co.'s Reservoir, Summit, N.J. *The same area Rephotographed after a single application of "Borascu"*

(Note that growths on the banks are essentially completely killed, while those growing in the water were not.)

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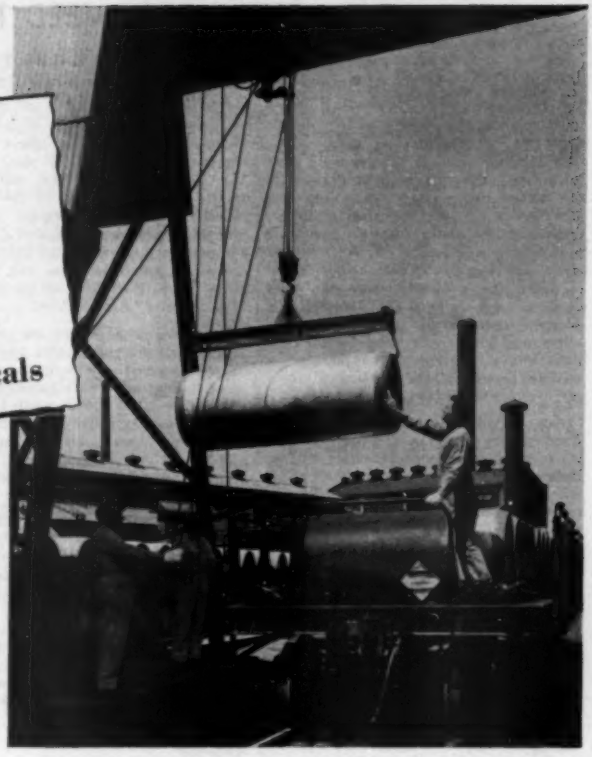

Hooker Chlorine in ton containers being loaded for shipment.

HOOKER LIQUID CHLORINE is supplied in tank cars containing 16 and 30 tons, multi-unit cars containing 15 one-ton containers, and cylinders containing 100 and 150 lbs. Hooker Chlorine is famous for its purity and uniformity. Careful manufacture and inspection are behind every shipment. Modern shipping facilities insure that shipments reach you on schedule and in good order.

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HOOKER CHLORINE BOOKLET No. 125 and CAUSTIC SODA BOOKLET No. 115 give physical and chemical properties, precautions in handling, and suggested equipment and materials for storing and handling.

HOOKER WALL CHART gives clear, readable instructions for safety in use and handling of chlorine in cylinders and ton containers. Ideal for hanging wherever you use or store chlorine.

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HANDLING AND USE OF CHLORINE*

CHLORINE in commerce is a liquefied gas under pressure. All types of containers used in the transportation of chlorine, as well as all means of transportation, are strictly governed by the regulations and specifications of the Interstate Commerce Commission.

This liquefied chlorine in containers has both a liquid phase and a gas phase. The loading density of any container is limited by regulations to allow about 12 per cent gas space in a full container at 68° F. Temperature affects both the vapor pressure and the volume of liquid chlorine.

As the temperature of liquid chlorine increases, the chlorine gas above the liquid exerts a greater pressure (except at exceedingly low temperatures). For example, the gage pressure of a chlorine container is normally about 82 psi. at 68° F. and is about 140 psi. at 100° F.

The volume of liquid chlorine becomes greater as its temperature increases. Thus, in a full container at 100° F., the gas space is reduced to less than 8 per cent. The gas space would become completely filled with liquid if the temperature reached 153.4° F.

Because of these characteristics, chlorine containers should be handled with care and should never be heated. The greatest danger from chlorine occurs through the development of leaks, since strong concentrations of chlorine in the atmosphere may cause serious physiological effects.

Properties of Chlorine

1. Chlorine, gas or liquid, is neither explosive nor flammable.

2. Gaseous chlorine has a characteristic highly irritating and penetrating odor. This characteristic odor gives warning of the presence of chlorine in the atmosphere before dangerous concentrations are attained. The greenish yellow color of chlorine gas makes it visible when high concentrations are present.

3. Gaseous chlorine is about two and one-half times as heavy as air and, therefore, if free, it flows to the floor or lower levels of a building.

4. Gaseous chlorine is only slightly soluble in water. WATER SHOULD NOT BE SPRAYED ON A CHLORINE GAS LEAK, because the corrosive conditions which result will make the leak worse and the heat supplied even by cold water will cause the liquid chlorine to change to gaseous chlorine at a faster rate.

5. Liquid chlorine is clear amber in color and is about one and one-half times as heavy as water. Under atmospheric pressure, liquid chlorine boils at about -30° F., changing to gaseous chlorine. Since it vaporizes with extreme rapidity if exposed to the atmosphere, liquid chlorine is rarely seen.

6. Upon vaporization, one pound of liquid chlorine forms about five cubic feet of chlorine gas; or, one volume of liquid chlorine yields approximately 460 volumes of chlorine gas. It is obvious that a liquid chlorine leak may be extremely hazardous as the quantity of chlorine discharged from a liquid leak will be many times greater than that discharged from a gaseous leak of the same size.

7. At ordinary temperatures, dry chlorine does not corrode steel or other common metals. In the presence of moisture, however, it is highly corrosive. Every precaution must be taken to keep the chlorine and chlorine equipment free from moisture. Pipe lines, valves, and containers should be tightly closed when not in use, since they will usually contain sufficient chlorine to quickly react with moisture from the air if left exposed.

Physiological Effects of Chlorine

1. Chlorine gas is classified as a respiratory irritant. In an atmosphere containing this gas, short, shallow breathing should be used. As chlorine is particularly irritating to persons afflicted with asthma and certain types of bronchitis, such persons should not be employed where it is possible to be exposed to chlorine.

2. When a sufficient concentration of chlorine gas is present in the atmosphere, it will irritate the mucous membranes, the respiratory system, and the skin. Relatively small amounts of chlorine can be detected because of the characteristic odor of the gas. Larger amounts cause irritation of eyes, coughing, and labored breathing. If the duration of exposure or the concentration of chlorine gas is excessive, it will result in general excitement of the person affected and will be followed by restlessness, throat irritation, sneezing, and copious salivation. The symptoms of advanced stages of exposure are retching and vomiting followed by difficult breathing. In extreme cases, the difficulty of breathing may increase to the point where death can occur from apparent suffocation. Chlorine produces no cumulative effects and complete recovery occurs from mild exposure. The physiological effects of various concentrations of chlorine gas are shown in Table A.

3. When liquid chlorine is exposed to the atmosphere, it vaporizes rapidly to chlorine gas and the resulting physiological effects will be those described above. Should liquid chlorine come in contact with skin or clothing, it may cause burns. Contaminated clothing should be removed immediately and the affected skin should be washed with large quantities of water.

TABLE A

Physiological Response to Various Concentrations of Chlorine Gas*

Effect	Parts of Chlorine Gas Per Million Parts of Air
Least detectable odor	3.5
Least amount required to cause irritation of throat	15.1
Least amount required to cause coughing	30.2
Least amount required to produce slight symptoms (of poisoning) after several hours' exposure	1.0
Maximum amount that can be breathed for one hour without serious effects	4.0
Amount dangerous in 30 minutes to one hour	40–60
Amount likely to be fatal after a few deep breaths	1000

*From United States Bureau of Mines' Technical Paper 248, "Gas Masks for Gases Met in Fighting Fires."

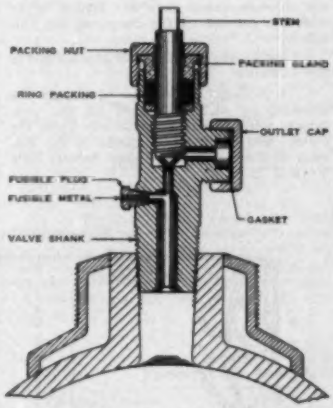

Fig. 1—Chlorine Institute Standard Cylinder Valve Screwed Type Fusible Metal Plug; There is also a Standard Poured Type Fusible Metal Plug

Chlorine Containers

Liquid chlorine is shipped in various sizes of cylinders containing from 1 to 150 pounds of chlorine; in ton containers containing 2000 pounds of chlorine; in multi-unit tank cars carrying 15 one-ton containers; in single unit tank cars containing 16, 30, 55 tons of chlorine; and in tanks on barges.

Cylinders

1. Chlorine cylinders are of seamless steel construction and comply with the specifications of the Interstate Commerce Commission. They are equipped with an approved type of cylinder valve. Fig. 1 shows a cross section of such valves. A protection hood is provided to cover the valve except when the cylinder is being emptied.

2. Special note should be made of the fusible metal plug in the valve. This plug is a safety device which has been designed to soften or melt between 158° and 165° F., allowing the contents of the cylinder to discharge. The fusible plug is below the valve seat and cannot be controlled by the valve. It is very important not to tamper with the fusible metal plug under any circumstances. Two types of fusible plugs are in general use in cylinder valves as indicated in Fig. 1.

Ton Containers

3. The chlorine ton container is a steel cylinder about 80 in. in length and 30 in. in outside diameter, complying in construction with the specifications of the Interstate Commerce Commission. Each end is dished, forming a chime which is crimped inward. The chime provides a substantial grip for hooks used in handling the containers. Each container is equipped with two valves which are located in one end near the center. Fig. 2 shows a cross section of such a valve. These valves are protected by a removable steel hood except when the container is being discharged.

*Reproduced from the *Chlorine Manual* of The Chlorine Institute.—Figures 1, 2, and 4 courtesy Solvay Sales Div.

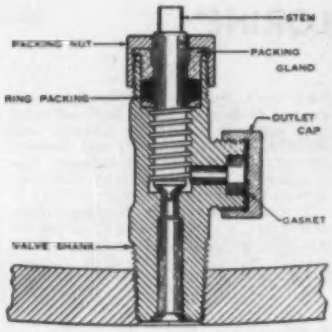

Fig. 2—Standard Ton Container Valve

4. The valves are identical and are connected inside the containers to eductor pipes as shown in Fig. 3. Thus, with the container lying on its side and the valves in a vertical line (one above the other as illustrated in the figure), the lower valve will discharge liquid chlorine and the upper valve will discharge chlorine gas from above the liquid level.

5. The valves are the same as cylinder valves, except that the ton container valve has no fusible metal plug and some containers are equipped with valves having slightly larger ports to provide for quicker discharge. The ton container is equipped with six fusible metal plugs, three in each end. The metal in these plugs has been designed to soften or melt between 158° and 165° F., allowing the contents of the container to discharge. It is very important that fusible plugs should not be tampered with under any circumstances.

Tank Cars

6. Liquid chlorine tank cars comply with Interstate Commerce Commission specifications. The tanks are constructed of welded steel and are provided with a covering of insulation which is in turn protected by a light steel jacket.

7. At the center on the top of the car is a circular steel housing, referred to as the dome, which contains all the valves on the tank. The two angle valves located on a line parallel with the length of the tank car are always arranged so that they will discharge liquid chlorine. Eduction pipes extending to the bottom of the tank are connected to these valves. Fig. 4 shows a cross section of such valves. The two angle valves at right angles to the length of the car will deliver chlorine gas. (Note: On 55-ton tank cars, one of these gas valves has been replaced with a second safety valve.) All angle valve outlets have one-inch standard tapered female pipe threads and these outlets are protected by one-inch plugs when not in use.

8. The safety valve is located at the center of the dome. On ICC 105A300 tanks, the valve is set to be vapor-tight at 180 psi. On ICC 105A500 tanks the valve is set to be vapor-tight at 300 psi. Consumers must never disturb safety valves.

9. Check valves are located in the eduction pipes under each of the liquid valves. The function of the check valves is to shut off the flow of chlorine in case there should be a very rapid increase in the flow of the liquid, such as might be caused by too rapid opening of the discharge valve or a rupture in the piping system. Check valves may also be located below the gas valve outlet.

Tank Barges

10. Tank barges and their chlorine tanks must comply with the Bureau of Marine Inspection and Navigation, U. S. Department of Commerce Regulations. The tanks are of welded steel construction and are not insulated. At the top and center of each tank there is a valve dome. The dome valves are of the type and arrangement of those on a 55-ton tank car, see "Tank Cars." The safety valves are set to be vapor-tight at 300 psi. Barges and their unloading are of a special nature and all details relating to them should be referred to the chlorine producer having such equipment.

Handling Chlorine Cylinders and Ton Containers

The following rules are recommended for handling, storing, and using chlorine containers. Where the word, "container," is used in the following paragraphs, it applies both to ton containers and to all cylinders.

1. IN AN EMERGENCY, TELEPHONE THE CHLORINE MANUFACTURER WHOSE NAME APPEARS ON THE CONTAINER. The name and address of the manufacturer and/or nearest chlorine producer should be posted in the office of the person in charge of chlorine handling, in the first aid room, and in the office of the plant manager.

2. Canister gas masks of a type approved by the U. S. Bureau of Mines for chlorine service should always be readily available where chlorine is being stored or transported or used. Gas masks should be located outside the probable area of contamination so that it will be possible to reach them in case of emergency. Where chlorine is used over wide areas, masks should be available in several locations.

3. Gas masks of the canister type do not supply oxygen; they absorb the chlorine present in the air leaving clean air to breathe. Where the chlorine content of the air is greater than 1 per cent, a self-contained oxygen breathing apparatus, or a fresh air hose mask should be used. All personnel that may be required to use gas masks should be properly instructed and required to practice their application and use. See National Safety Council Pamphlet No. 64, "Respiratory Protective Equipment."

4. It is illegal to ship cylinders containing chlorine unless they are loaded by or with the consent of the owner of the cylinders.

5. Never mix chlorine and another gas in the container.

6. It is illegal to remove or change the numbers or marks stamped on the containers without written authority from the owner, and written notification to the Bureau of Explosives, 30 Vesey Street, New York 7, N. Y.

7. It is illegal to ship a leaking container, whether full or partially full. It is illegal to ship chlorine in containers that have been exposed to fire. Consult your supplier for advice under these circumstances.

Moving

1. Never drop containers or permit them to strike each other with any force.

2. Never use a lifting magnet or a sling (rope or chain) when handling containers. Hoisting should be avoided as much as possible. Where hoisting is necessary, the use of safe lifting clamps is recommended. A suitable lifting clamp for handling chlorine ton containers is illustrated in Fig. 5.

3. To move cylinders about, use a hand truck properly balanced and preferably with a clamp support at least two-thirds of the way up the cylinder.

4. Consult your supplier for detailed information regarding the unloading of ton containers.

Storing

1. All containers should be stored in a cool place and protected against external heat sources.

2. Never store containers near combustible or flammable materials. Chlorine containers should be segregated.

3. Containers should not be stored where they are exposed to continuous dampness.

4. Cylinders should be stored in an upright position. Ton containers should be stored on their sides on a level rack which may be constructed of I-beams or two railroad rails properly supported a few inches off the ground.

5. Valve protection hoods on ton containers and cylinders should always be kept in place except when containers are being emptied. Do not hoist cylinders by the hood.

6. Store full and empty containers in different places to avoid confusion in handling them. It is good practice to tag empties.

7. Do not store containers near elevators or gangways or in locations where heavy objects may fall and strike them.

8. The storage room should be well ventilated, and the containers so arranged that any container can be removed with a minimum of handling of other containers. Where practical, the storage room should be fireproof. Storage in subsurface locations should be avoided.

9. Containers stored out of doors should be protected against direct exposure to the sun and against accumulation of snow or other material that may build up around them. They should be kept clean and should be inspected regularly.

10. Never store containers or place leaking containers where the fumes can enter a ventilating system.

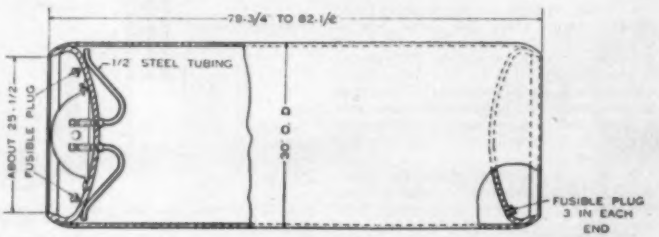

Fig. 3—Chlorine Ton Container, End and Side Views

Using

1. Use containers in the order in which they are received.

2. Never tamper with the safety devices on containers.

3. Open container valves slowly. The use of large wrenches or pipe wrenches will damage the valves. One complete turn of the valve stem in a counterclockwise (lefthand) direction opens the valve sufficiently to permit maximum discharge. Do not use a wrench longer than 6 inches on a container valve.

4. In making a connection to the valve outlet, clamps and adaptators are recommended. In case threaded connections are used, make sure that the threads on appliances and unions are the same as those on container valve outlets. Never force connections that do not fit. The outlet threads on the valves of containers are not tapered pipe threads.

5. Containers or valves should never be altered or repaired by the consumer.

6. Gas leaks around the valve stem may usually be checked by tightening the packing nut.

7. To test for chlorine leaks: Attach a cloth to one end of a stick, soak the cloth with ammonia-water, and apply to the suspected area. A white cloud of ammonium chloride will result if there is any chlorine gas leakage.

8. As soon as containers are empty, close their valves, disconnect, and test for chlorine leaks as described in par. 7 above, at the valve outlets. If no leakage is indicated, apply cap nuts to valve outlets, and attach valve protection hoods securely in their proper places. These fittings should always be kept in place except when the container is being emptied. The open end of the line leading from the container should be plugged or capped immediately to keep moisture from entering the system.

9. Return empty containers promptly.

10. Use only reducing valves and gages designed for chlorine. Consult the chlorine producer for details.

11. Never apply heat directly to any container. Containers should be discharged in a room which has a temperature of about 70° F. If the rate of gas evolution from a single container is not sufficient, consult your chlorine or chlorine equipment supplier for detailed information.

12. Cylinders of 150 pounds capacity or less will deliver chlorine gas when unloaded in an upright position and will deliver liquid chlorine when unloaded in an inverted position. The ton containers in a horizontal position and with the valves in a vertical line (one above the other as shown in Fig. 3) will deliver liquid chlorine from the lower valve and chlorine gas from the upper valve.

13. If chlorine is being absorbed in a liquid, there is a tendency for the liquid to suck back into the cylinder or container due to creation of a partial vacuum when the cylinder or container becomes empty. This should be avoided as it has resulted in numerous accidents. Consult your chlorine or equipment supplier before proceeding with this operation.

14. Always empty cylinders and ton containers on a scale, in order to know at all times the amount of chlorine in the cylinder or ton container.

Handling Chlorine Tank Cars

1. The following special rules are recommended where chlorine is being handled in tank car quantities. These rules are in addition to those of a general nature set forth above, and which are applicable to all types of chlorine container handling.

2. Single unit cars must be unloaded only on a properly protected private track of the consumer, or on a leased track, in accordance with regulations of the Interstate Commerce Commission. In the case of multiple unit cars, where no private track is available, the ton containers may be removed from the under frame at a public siding if in accordance with Interstate Commerce Commission regulations.

3. Switch tracks on which chlorine cars are placed for unloading should be devoted solely to this purpose.

4. When a chlorine tank car is spotted on a siding for unloading, brakes must be set and wheels blocked. Interstate Commerce Commission regulations require the following: "Caution signs must be so placed on the track or car as to give necessary warning to persons approaching car from open end or ends of siding and must be left up until after car is unloaded and disconnected from discharge connection. Signs must be of metal, at least 12 by 15 inches in size and bear the words, 'STOP—Tank Car Connected,' or 'STOP—Men at Work,' and word, 'STOP,' being in letters at least 4 inches high and the other words in letters at least 2 inches high. The letters must be white on a blue background."

5. When tank cars are located on a dead end siding, the cars should be protected on the switch end by a derail. If on an open siding, derails should be provided at both ends. Keys for the derails should be in charge of a responsible person.

6. Unloading of single unit chlorine tank cars should be done through a flexible metal connection. (Note: Owing to the varying nature of locations of single unit tank cars placed for unloading, and to the length, arrangement, and other features of the unloading line from the tank car, no general specification for the unloading line is practical. For all details relating to the unloading line, consult the chlorine producer.) A flexible connection, however, should not be depended upon as a safety factor in case of a bump by switching operations during unloading. (Note: Derails should be in place as stated in paragraph 4 above, and red lanterns should be suitably placed if unloading is done at night.) Unloading, connecting, and disconnecting operations should be performed only in well-lighted places by reliable persons who are properly instructed and made responsible for operations and who are equipped with chlorine gas masks.

7. Tank car outlet valves should be kept closed when operator of chlorine line is not on duty. The pipe line beyond the tank car valve should not be left full of liquid chlorine during shut-down periods because trapping of liquid chlorine may result in broken lines and leakage.

8. When ready to discharge liquid chlorine from a single unit tank car, open tank car liquid angle valve slowly about two turns and control chlorine flow with regulating valve on end of unloading line.

9. If the check valve closes and liquid chlorine will not flow, it may be released by closing the discharge valve completely and leaving it closed until the metal ball in the check valve falls back into place. A noticeable click will be heard when this occurs.

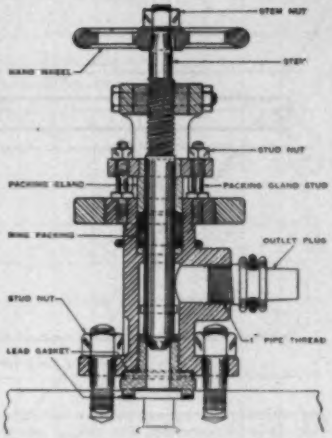

Fig. 4—Chlorine Angle Valve for Tank Cars

10. It is illegal to ship a defective or leaking chlorine tank car. If a tank car is in bad order or if there is an accident, telephone the car owner or the nearest chlorine plant for assistance.

11. Heat must never be directly applied to tank cars. It may, however, be desirable in some locations which are subject to low winter temperatures, to unload the tank cars in a shed maintained at 70 to 75° F. In certain cases, however, particularly in winter weather with its low outside temperature, the pressure in single unit cars may not be adequate and it may then be necessary to increase it by the addition of dried compressed air to secure the rate of discharge desired. Only thoroughly dried clean air may be used for this purpose and it should be supplied by a separate air compressor which is used only for this service; an existing compressed air system should never be connected to the chlorine tank car. The air drier must be of suitable capacity to supply the full requirements and it must be maintained in proper operating condition. Consult the chlorine producer for all details relating to the application of dry air to single unit tank cars.

12. If the use of chlorine is at an elevation materially above that of the tank car, high pressure will be required in the car to force the liquid to the higher elevation. It is much safer to locate a chlorine evaporator at the elevation of the tank car and pipe the gaseous chlorine to the higher elevation. Consult the chlorine producer for all details relating to the design and use of evaporators.

Chlorine in Public and Semi-Public Buildings

Chlorine is one of the standard agents for disinfecting swimming pool water. The use of liquid chlorine for this purpose at indoor swimming pools should be recognized as potentially hazardous. Indoor swimming pools are usually located below ground level where, in the event of a chlorine leak, access to the chlorine cylinders

TABLE B

Recommended Alkaline Solutions for Absorbing Chlorine

Chlorine Container Size—Pounds Net	Caustic Soda Pounds 100%	Caustic Soda Water Gals.	Soda Ash Pounds	Soda Ash Water Gals.	Hydrated Lime Pounds	Hydrated Lime Water Gals.
100	125	40	300	100	125	125
150	188	60	450	150	188	188
One Ton	2500	800	6000	2000	2500	2500

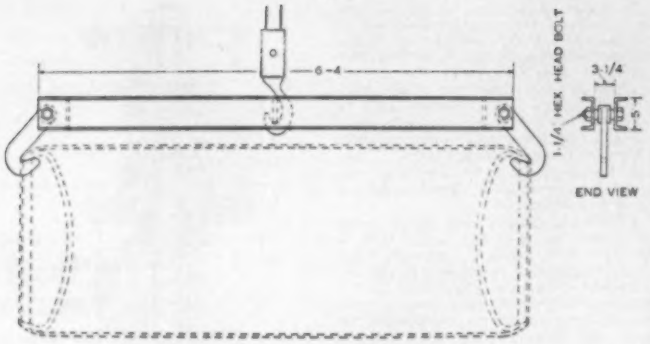

Fig. 5—Lifting Clamp for Chlorine Ton Containers

and chlorinating equipment may be difficult. It is recommended that special safety precautions be provided where liquid chlorine must be stored or used in public and semi-public buildings.

Employee Protection

Emergency Measures

1. These suggestions are based on the experience of chlorine producers, and are presented as helpful information on the handling of chlorine. It should not be assumed that every acceptable safety procedure is contained herein, or that abnormal or unusual circumstances may not require additional procedures.

2. *As soon as there is any indication of the presence of chlorine in the air, steps should be taken to correct the condition. Chlorine leaks never get better. Chlorine leaks always get worse if they are not corrected promptly. Telephone your chlorine supplier or any chlorine producer if you need help.*

3. Keep on the windward side of the leak and higher than the leak.

4. When a chlorine leak occurs, authorized, trained personnel equipped with gas masks should investigate. For recommendations relating to gas masks, see Handling Chlorine, Cylinders and Ton Containers par. 1, 2 and 3. All other persons should be kept away from the affected area until cause of the leak has been discovered, and the trouble corrected. If the leak is extensive special effort must be made to warn all persons in the path of the fumes.

5. Where a leak occurs in equipment in which chlorine is being used, the chlorine container valve should be closed immediately.

6. If a chlorine container is leaking in such a position that chlorine is escaping as a liquid, the container should be turned so that chlorine gas escapes. The quantity of chlorine escaping from a gas leak is about one-fifteenth the amount that escapes from a liquid leak through the same size hole.

7. Do not apply water to a chlorine leak. The application of a stream of water to a chlorine leak is hazardous and makes the leak worse due to the corrosive action of chlorine and water.

8. If a chlorine leak occurs in transit in a congested area, it is recommended that the conveyance keep moving if possible until it reaches an open area, where the escaping gas will be less hazardous. If a chlorine leak occurs in transit and the conveying vehicle is wrecked, the container or containers should be shifted so that chlorine gas is escaping. If possible, the containers should then be transferred to a suitable conveyance and transported to the open country.

9. Pin-hole leaks in cylinders and ton containers may sometimes be temporarily stopped by driving a tapered hard-wood peg or metal drift pin in the hole. The container should be turned so that only gas is escaping before attempting to stop the leak. Extreme care should be exercised in driving in the plug, as the wall area surrounding the hole may be thin and crumble, thereby making the leak worse. When this emergency measure is taken, the cylinder must always be emptied of its contents as quickly as possible.

10. At regular points of storage and use, emergency preparations for disposing of chlorine from leaking cylinders or ton containers should be made. Chlorine may be absorbed in caustic soda, soda ash, or hydrated lime solution. Caustic soda is recommended as it absorbs chlorine most readily. The proportions of alkali and water preferred for this purpose are given in Table B.

11. A suitable container to hold the solution should be provided in a convenient location. The chlorine may be passed into the solution through an iron pipe or rubber hose properly weighted to hold it under the surface. Discuss the details of such preparations with your chlorine producer.

Prophylactic Measures

The following prophylactic measures are recommended for persons who may be exposed to chlorine.

Prophylaxis, 1. Provide physical examinations including chest X-ray of applicants and of employees handling chlorine.

Prophylaxis, 2. Provide instructions and approved gas masks for all employees handling chlorine.

First Aid Measures

The following first aid measures are recommended for persons exposed to chlorine:

First Aid, 1. Carry patient from gas area. Patient should preferably be kept in a warm room (about 70° F.). Supply blankets if necessary. Keep patient warm and quiet. Rest is essential.

First Aid 2. Place patient on back with head and back elevated.

First Aid, 3. CALL A PHYSICIAN IMMEDIATELY.

First Aid, 4. Splashes of liquid chlorine and chlorinated water destroy clothing, and if such clothing is next to the skin will provide irritation and acid burns. In such cases remove clothes and keep patient warm with blankets.

First Aid, 5. Carbon dioxide and oxygen mixture with not to exceed 7 per cent of carbon dioxide may be given. This mixture, ready prepared, and sold with the necessary apparatus, can be administered intermittently for periods of two minutes followed by two-minute rest periods over a total period not to exceed thirty minutes. Instructions of the purveyor of the gas apparatus should be carefully obeyed. If carbon dioxide and oxygen mixture is not readily available, oxygen alone may be used.

First Aid 6. Milk may be given in mild cases as a relief from throat irritation.

First Aid, 7. If breathing has apparently ceased, start immediately the artificial prone pressure method of resuscitation (Schafer). Do not exceed 18 movements per minute.

First Aid, 8. Provide First Aid as may have been prescribed for emergencies by your company physician pending his arrival.

Chemical Characteristics and Physical Properties of Chlorine

Chlorine gas was discovered in 1774 by C. W. Scheele, a Sweedish chemist, but he regarded it as a compound substance. The gas was first liquefied by Thos. Northmore in 1805. It was identified as an element in 1810 by Sir Humphrey Davy, who proposed the name chlorine and the symbol Cl from "chloros," the Greek word meaning green .

The chlorine of commerce is usually manufactured by the electrolysis of a solution of sodium chloride or potassium chloride. Gaseous chlorine so produced is dried and purified, then is liquefied by compression and refrigeration.

The following list describes some of the important chemical and physical characteristics of chlorine. The source of all data is given in Section N, page 30, of *The Chlorine Manual.*

Action on Metals

At ordinary temperatures dry chlorine, gaseous or liquid, does not attack copper, iron, lead, or steel. Moist chlorine is very corrosive to all common metals, but gold, platinum, and silver are resistant. At tem-

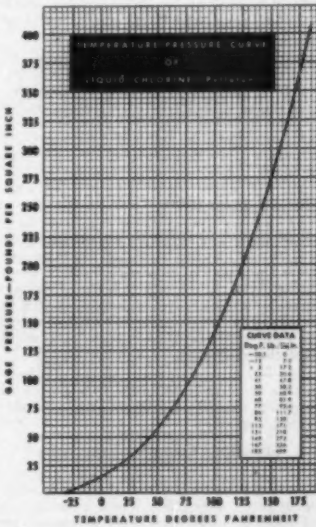

Fig. 6—Temperature-Pressure Relation of Liquid Chlorine

peratures below 150° C. (302° F.), tantalum is totally inert to wet or dry chlorine. At low pressures moist chlorine is frequently handled in earthenware, glass, or porcelain equipment; special high silica iron alloys, Monel, and Hastelloy "C" also exhibit good resistance.

Atomic and Molecular Data

The atomic and molecular characteristics of chlorine follow.

Atomic symbol:	Cl
Atomic weight:	35.457
Molecular symbol:	Cl_2
Molecular weight:	70.914
1 gm. mol. of chlorine =	70.914 gm.

Boiling Point

—34.5° C. (—30.1° F.). The temperature, under 1 atmosphere pressure, at which liquid chlorine boils or the gas liquefies. Alternate term is liquefying point.

Color

Gaseous chlorine is greenish yellow in color. Liquid chlorine is clear amber in color.

Critical Pressure

76.1 atmospheres, or 1118.7 lb. per sq. in absolute pressure. The vapor pressure at the critical temperature.

Critical Temperature

144° C. (291.2° F.). The temperature above which chlorine exists only as gas, no matter how great the pressure.

Density, Gaseous Chlorine

1 liter of dry chlorine weighs 3.214 gm. at 0° C. (32° F.) and 1 atmosphere pressure.

Density, Gaseous Chlorine

1 liter of saturated chlorine weighs 12.8 gm. at 0° C. (32° F.) and 3.65 atmospheres pressure or 39.0 pounds gage pressure.

Density, Liquid Chlorine

1 liter weighs 1468 gm. at 0° C. (32° F.) and 3.65 atmosphere pressure or 39.0 pounds gage pressure—Temperature-Density Relation of Liquid Chlorine.

Flammability

Chlorine, gaseous or liquid, is non-explosive and non-flammable. Gaseous chlorine will support the combustion of certain compounds.

Latent Heat of Vaporization

68.8 calories per gram at —34.05° C., or 123.8 B.t.u. per pound at —29.3° F. The heat units required to evaporate a unit weight of liquid chlorine.

Liquid-Gas Volume Relation

1 volume of liquid chlorine is equivalent to 456.8 volumes of gaseous chlorine at 0° C. (32° F.) and 1 atmosphere pressure. 1 pound of liquid chlorine is equivalent to 4.98 cu. ft. of gaseous chlorine at 0° C. (32° F.) and 1 atmospheric pressure.

Melting Point

—100.98° C. (—149.76° F.). The temperature, under atmospheric pressure, at which the solid melts or the liquid solidifies. Alternate term is freezing point.

Odor

Chlorine has a characteristic penetrating and irritating odor. (See Table A.)

Reactivity

Chlorine has a very strong chemical affinity for other substances. It will react with almost all the elements and with many inorganic and organic compounds, usually with the simultaneous evolution of heat.

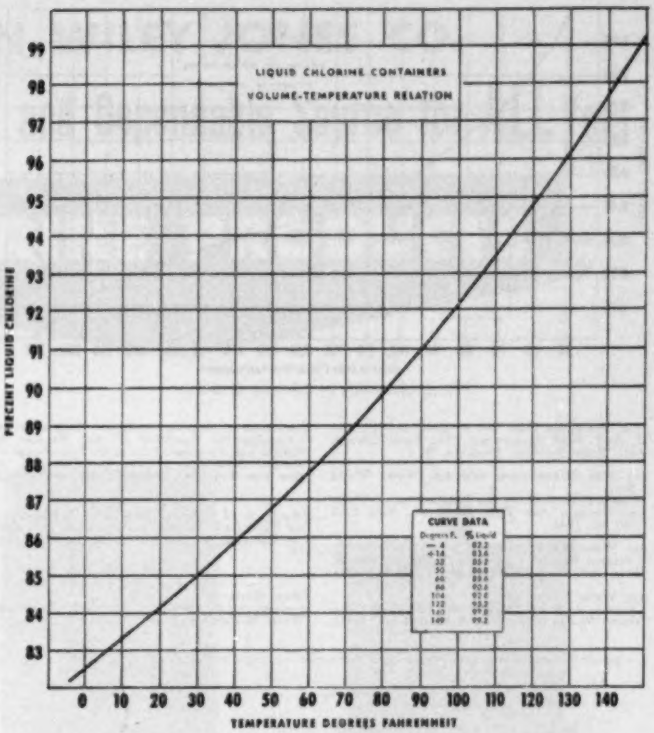

Fig. 7—Temperature-Volume Relation in Liquid Chlorine Containers

Solubility, Gaseous Chlorine

The volume of chlorine gas, in terms of 0° C. (32° F.) and 1 atmospheric pressure, which can be dissolved in water at a given temperature when the added vapor pressure of the gas and the solvent equals 1 atmosphere. Below 9.6° C. (49.3° F.) chlorine combines with water to form a solid hydrate, $Cl_2 8H_2 0$. See Fig. 8—Solubility of Chlorine in Water.

Specific Gravity, Gaseous Chlorine

2.49. The relative density, at 0° C. (32° F.) and 1 atmosphere pressure, compared with air as unity.

Specific Gravity, Liquid Chlorine

1.47. The relative density, at 0° C. (32° F.) and 3.65 atmospheres pressure, or 39.0 pounds gage pressure.

Specific Heat, Gaseous Chlorine

0.115 calorie per gram per °C. at 15° C., or 0.115 B.t.u. per pound per °F. at 59° F., at constant pressure. At constant volume the specific heat is 0.0849. The ratio of Cp/Cv = 1.355. The heat units required to raise the temperature of a unit weight of gaseous chlorine one degree.

Specific Heat, Liquid Chlorine

0.226 calorie per gram per °C. between 0° and 24° C., or 0.226 B.t.u. per pound per °F. between 32° and 75° F. The heat units required to raise the temperature of a unit weight of liquid chlorine one degree.

Vapor Pressure

The pressure above liquid chlorine when liquid and gas are in equilibrium. See Fig. 8—Temperature-Pressure Relation of Liquid Chlorine.

Volume, Gaseous Chlorine

1 pound occupies 4.98 cu. ft. at 0° C. (32° F.) and 1 atmosphere pressure (Ref. 4).

Volume, Liquid Chlorine

1 pound occupies 0.011 cu. ft. at 0° C. (32° F.) and 3.65 atmospheres pressure or 39.0 pounds gage pressure (Ref. 5).

Volume-Temperature Relation

The volume of liquid chlorine increases rapidly as its temperature increases. The I.C.C. Regulations limit the loading density of chlorine containers to provide gas space in a full chlorine container at room temperature. A full chlorine container becomes completely filled with liquid when the temperature of the liquid reaches about 62.4° C. (153.4° F.). See Fig. 7—Temperature-Volume Relation in Liquid Chlorine Containers.

Weight, Gaseous Chlorine

1 cu. ft. weighs 0.2006 pounds at 0° C. (32° F.) and 1 atmosphere pressure.

Weight, Liquid Chlorine

1 cu. ft. weighs 91.64 pounds at 0° C. (32° F.) and 3.65 atmospheres pressure or 39.0 pounds gage pressure.

Selected References

A complete list of references on chemical and physical constants and on chlorine is given in Section N., page 30ff of *The Chlorine Manual*. Here is a list of selected references.

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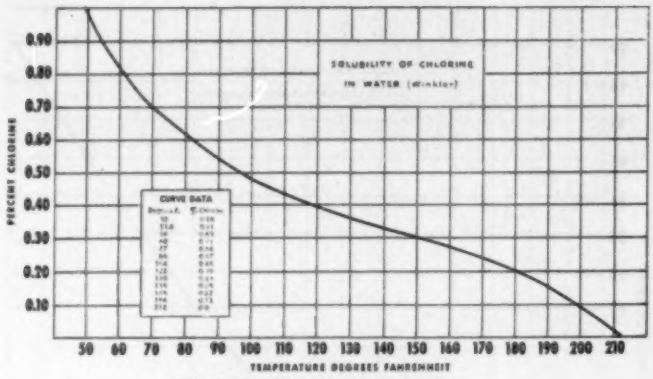

Fig. 8—Solubility of Chlorine in Water

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WEIGHTS OF MATERIALS

Pounds per Cubic Foot — Average

BRICK	
Common Red	100
Silica	105
CEMENT	
Portland	94
Hydraulic	60
COAL AND COKE	
Anthracite	53 to 57
Bituminous	49
Charcoal	18
Coke	26
CONCRETE	
Cement, fine	137
Rubble, coarse	119
EARTH	
Loam, dry, loose	76
Loam, packed	95
Loam, soft, loose mud	108
Loam, dense mud	125
LIME	
Quick, loose lumps	53
Quick, fine	73
LIME STONE	
Large blocks	168
Irregular lumps	96
MASONRY	
Granite or limestone	165
Mortar, rubble	154
Dry	138
Sandstone, dressed	144
METALS	
Aluminum	166
Brass, cast	524
Bronze	534
Copper, cast	537
Copper, rolled or wire	555
Iron, cast	450
Iron, wrought	482
Lead, cast	708
Lead, rolled	711
Steel, cast	490
Steel, rolled	495
Tin, cast	459
Zinc, cast	438
OILS	
Engine	55
Crude	48
Petroleum	55
Gasoline	43
SAND	
Dry and loose	100
Dry and packed	110
Wet and packed	130
Gravel, packed	118
Gravel, bank	111
Gravel, dry	74
WATER	
Water, as ice	59
Water, at 32° F.	62
Water, at 212° F.	60

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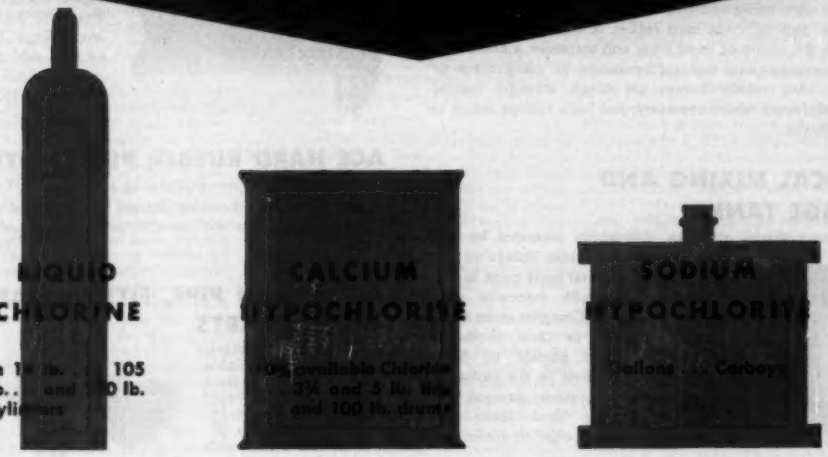

There are good reasons why so many municipalities, government agencies, processors and manufacturers turn to JONES for CHLORINE products. Whether for purification of drinking water, chlorination of sewage and industrial wastes, or bacteria control in swimming pools, they know that the *uniform* top quality of JONES CHLORINE products will meet their most stringent requirements.

Scientifically prepared to satisfy high government standards, they have been specified for years by the U. S. Army and Navy as well as hundreds of cities and private concerns throughout the nation. When you order from JONES, you get the *right* chlorine product to exactly fit your needs and shipped in the most convenient and economical container.

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AMERICAN HARD RUBBER COMPANY

11 MERCER STREET, NEW YORK 13, N. Y.
Representatives: 111 W. Washington St., Chicago 5, Ill.; Akron 4, Ohio

Ace Rubber Protected Equipment for Water Purification and Sewage Disposal Plants

ACE HARD RUBBER AND ACE RUBBER LINED EQUIPMENT

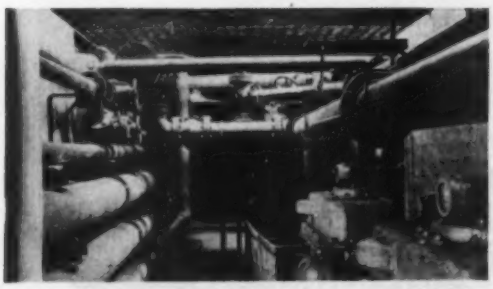
Handles all phases of storage, pumping and piping problems in connection with ferric chloride and chlorine water treatment and sewage disposal. Ace hard rubber is chemically inert and resistant to the action of most acids and corrosive solutions. It prevents corrosion and rust contamination in many types of equipment. Ace rubber linings are tough, strongly bonded specially reinforced where necessary, and high voltage tested to insure perfection.

CHEMICAL MIXING AND STORAGE TANKS

All sizes and shapes of tanks, thoroughly protected by Ace hard rubber linings so that no metal parts come in contact with corrosive solutions. Complete tanks available, or Ace protective linings applied to tanks furnished by the customer. Also rubber covered and rubber lined filters and other special equipment.

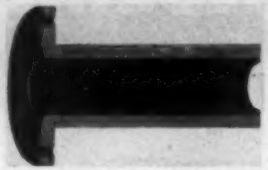
ACE RUBBER-PROTECTED PUMPS

Made in several sizes and types, with some parts made of solid Ace hard rubber, and other parts lined with Ace rubber for adequate corrosion resistance. Ace Type W.A.M. centrifugal pump illustrated, for medium capacities up to 90 g.p.m. at 12 ft. head. Excellent for pumping all water-treating chemicals. Ace pumps with capacities up to 300 g.p.m. at 40 ft. head also available.



In this sewage installation, Ace hard rubber lined pipe, valves, fittings; Ace solid hard rubber pipe and fittings, and an Ace rubber-lined tank were used for maximum corrosion resistance.

ACE RUBBER-LINED PIPE & FITTINGS



Combines strength of steel and acid resistance of Ace rubber linings. Fully protected through pipe and over flange faces. Hard or soft rubber linings as required. All flanged, in sizes from 1½ in. up.

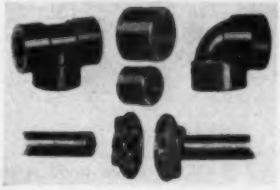
ACE HARD RUBBER PIPE & FITTINGS

Solid hard rubber pipe available in sizes from ½" to 8" inclusive. Ace solid hard rubber flanged and threaded pipe fittings available in all sizes and types for permanent chemical-handling lines.

ACE SARAN PIPE, FITTINGS AND MOLDED PARTS

Chemically resistant, strong plastic available from Ace in pipe sizes from ½" to 2" with standard Ace Saran fittings from ½" to 2". Easily butt-welded with heat. ½" to 1¼" Ace Saran Diaphragm Valves. Special molded parts available.

Write for Ace Saran Bulletin.



ACE RUBBER LINED VALVES

GATE VALVES, hard rubber lined available in sizes 2" to 12" inclusive except 2½" size.

DARLING GATE VALVES, hard rubber lined, with special metal trim for the required service. In sizes 2" to 20" inclusive.

DARLING CHECK VALVES, non-slam, for vertical or horizontal operation. Sizes 2" to 12" with internal special chemical-resisting metal parts.

DIAPHRAGM VALVES, rubber lined, sizes from 1" to 6" inclusive. (Hills-McCanna Co., Saunder Patent.)

64 PAGE CATALOG →

Covering all types of Ace Rubber Protected Equipment, available upon request. You'll want this reference when specifying maximum corrosion resistance and *longer* equipment life with Ace protection. Write also for the Ace Saran pipe and fittings bulletin.

FINANCING SEWAGE WORKS

Some Fundamental Considerations

by WM. F. TEMPEST,*

Portland Cement Association, Chicago, Ill.

OF ALL the utility services enjoyed by any community the most essential are water and sewage works. Practically, the two services are so closely related they may be considered as one. After considering real values few will take issue with such a statement. A plentiful supply of safe water requires adequate protection and elimination of pollution. This in turn means adequate treatment works for all communities returning used water containing sewage and other impurities to water courses or ground waters. With the increase in population and the development and extension of urban communities the need for providing treatment works has become more acute. Fortunately the problem is one that is now being given more attention by all officials of local units of government.

High standards of living, bordering upon extravagance, are likely to create a false sense of values. It may be more popular in some places to advocate a community golf course rather than a sewage treatment plant, just as in a home the most needed item may be a new washing machine, but the one most desired may be a television set. Municipal officials of the community, no less than individual members of a family, are faced with the problem of maintaining a balance in providing all the services demanded including essential and the not so essential but desirable. The ever present problem for the municipality as well as the family is one of paying for the desired service or improvement.

Elementary Factors

The elementary factors affecting municipal financing of improvements are the same as those applicable to an individual. Too often individuals who make up a city council or officials who administer the affairs of a community overlook fundamentals. At the risk of oversimplification all of the problems incident to the financing of sewage works will be discussed as factors of a simple formula for borrowing money, sometimes referred to as the three "C"s, that is

$$C_1 + C_2 + C_3 = C_4$$

Where C_1 is Capital
C_2 is Capacity
and C_3 is Character

With variable values, the sum of these equals C_4, which is *Credit* or trust in a promise for repayment of borrowed funds.

The value assigned to C_1 (Capital) will, of course, depend upon cash resources, value of properties, equipment, etc. It is a fundamental consideration but not the most important of the three factors.

The value assigned to C_2 (Capacity) is perhaps the most important when considered together with C_3 (Character), as it will generally be determinative of the final result. The earning power existing, or potential, is the measure of the capacity of a municipality to pay for improvements over a period of time. The lender will make a careful study of this factor. The value assigned to C_3 (Character) is also carefully weighed by a lender. Although merely a legal entity, the municipality or other local unit of government has character no less than a natural person when finance is considered. The integrity of a municipality, its past experience in the discharge of obligations, the type of administration and the published reports all influence an appraisal of its character.

These simple factors and a broad comprehension of what each means to the future of the community should be kept constantly before administration officials. The values are not determined overnight but only as the result of experience and a course of conduct appearing on record.

Revenue Bond Report

To illustrate a form of inquiry adopted by the Investment Bankers Association of America, both sides of two Revenue Bond Report forms for improvements are reproduced herewith. The answers to the questions on these forms together with a copy of the latest financial statement and additional comments will enable the lender or the investor to analyze the security issued in the light of the fundamental factors discussed.

These forms were prepared by the Municipal Securities Committee of the Investment Bankers Association in an effort to have necessary information collected and presented in a uniform pattern and as concise as possible. It is offered as a constructive suggestion with the hope that issuers of revenue bonds will follow it as closely as practicable in making information available to engineers. The necessity for this arises out of the development of revenue financing and the growing interest on the part of the investing public.

Application of Principles

In the past few years much has been written and considerable study undertaken on problems affecting the financing of water and sewage facilities. Of particular significance is the work of a Joint Committee sponsored by the American Society of Civil Engineers and the Section of Municipal Law of the American Bar Association. Participating organizations included:

American Water Works Association
Federation of Sewage Works Associations
Investment Bankers Association of America
Municipal Finance Officers Association
American Public Works Association
National Association of Railroad and Utilities Commissioners

The report of this joint group† has value for all those interested in the financing or administration of water and sewage works.

The report covers all phases but with particular emphasis upon the establishment of a sound basis for the rate structure and fair rates to meet the total annual revenue requirements.

The total annual revenue required is defined substantially in the following manner—

"The needed total annual revenue of a water or sewage works shall be contributed by users and non-users or properties for whose use, need and benefit the facilities of the works are provided, approximately in proportion to the cost of providing for the service and for the use of the works."

Three Types of Bonds

This fundamental concept of a rate structure designed to impose regular charges based upon service and benefits enables the municipality to operate the water and sewer facilities on a businesslike basis. It permits the finance officer to develop a well-rounded financial plan. Too often, the only available method of borrowing has been by means of general tax obligation bonds relying solely on the taxing power.

General Tax Obligation bonds are payable from a general tax on all property and consequently a direct obligation of the municipality. All bonds of this class fall within Constitutional or statutory limitations upon indebtedness. No distinction is made between revenue producing public works. Total reliance upon this method prevents flexibility and may seriously retard construction of needed improvements.

Special Assessment bonds although payable only from special assessments against property benefited nevertheless make the property owner responsible for the improvement and are considered an indebtedness of the municipality.

Revenue bonds, the third method of financing, provide for repayment from charges to be made against users, or users and properties. Such bonds are ideally suited for the financing of sewage works. Insofar as any local unit of government has some capital, good capacity for earnings, a good character and stability with honest administration, revenue bonds will be acceptable to the investor and provide an economical means of raising funds for vital needs.

Organizing An Improvement

The success of any improvement depends not only upon the soundness and the need for the project but also upon engineering judgment, well-planned financing and carefully guided legal procedure. In support of all phases there should be strong public support. No municipality should overlook this important preliminary step. It may even be profitable to engage special counsel to direct an educational campaign.

The first step by the officers of the municipality should be the organization of a committee of leading citizens who have the confidence of the entire community.

The second step will be the actual organization and conduct of the campaign. Accurate information, honestly presented, will have a salutary effect upon acceptance of the financial plan and the subsequent sale of the securities to the investor.

It is at this point that the value of "character" will be appreciated. If the municipal officials have issued interesting and informative annual reports and if good public relations have been built up with all utility users the campaign for support of new facilities or extensions will gain momentum rapidly. The following outline of a general educational campaign has been used successfully and is offered as a suggestion for others:

Educational Campaign Outline

A. Establish central committee
  1. Headquarters

*Secretary, Section of Municipal Law of the American Bar Assn., which is preparing a Joint Report with the ASCE Committee on Rates and Rate Structures for Water and Sewage Works.

†The report of the Joint Committee is scheduled for publication in the second quarter of 1951.

IBA FORM

Revenue Bond Report—Form No. 1

_____
(Name of issuing governmental body)

Information regarding its:
(check type of facility)

( ) ELECTRIC LIGHT AND POWER REVENUE BONDS, OR
( ) SEWER REVENUE BONDS, OR
( ) TOLL BRIDGE OR HIGHWAY REVENUE BONDS, OR
( ) WATER REVENUE BONDS

Population of area served_____ (U. S. Census 19____) Date of issue_____

Amount authorized $_____ Amount issued $_____

Maturities

Amount	Rate	Date	Amount	Rate	Date	Amount	Rate	Date
$_____	____	_____	$_____	____	_____	$_____	____	_____
_____	____	_____	_____	____	_____	_____	____	_____
_____	____	_____	_____	____	_____	_____	____	_____
_____	____	_____	_____	____	_____	_____	____	_____
_____	____	_____	_____	____	_____	_____	____	_____
_____	____	_____	_____	____	_____	_____	____	_____
_____	____	_____	_____	____	_____	_____	____	_____
_____	____	_____	_____	____	_____	_____	____	_____

Call provisions, if any. If noncallable prior to maturity please so state.

_____

_____

_____

What is purpose of issue?_____

_____

If purpose is for new construction or development give engineer's estimate of gross and net revenue expected over next five years:

Gross	$_____	$_____	$_____	$_____	$_____
Net	$_____	$_____	$_____	$_____	$_____

What is peak requirement for interest and principal or sinking fund?_____

What year is peak reached?_____

Amount of outstanding revenue or other bonds which have a claim on the revenue from this project $_____

(a) Are there securities having a claim junior to this issue? Yes_____ No_____ If "Yes", show
Amount $_____ Maturity _____ Peak debt service requirements $_____

(b) Are there securities having a claim equal to this issue? Yes_____ No_____ If "Yes", show
Amount $_____ Maturity _____ Peak debt service requirements $_____

(c) Are there securities having a claim prior to this issue? Yes_____ No_____ If "Yes", show
Amount $_____ Maturity _____ Peak debt service requirements $_____

Schedule of rates or charges for services of the facility. Date effective_____ (Give particulars in a separate statement)

Attach condensed report of income and expenditures for the last fiscal year, compared with the same information for the same period during the preceding two years; also latest balance sheet. For the purpose see accompanying Report Form No. 2 Electric, or No. 2 Sewer, or No. 2 Toll Bridge or Highway, or No. 2 Water, depending upon the type of the facility.

(See reverse side)

Controlling covenants of the bond indenture, authorizing resolution or act. Attach separate statement, if necessary.

(a) In what order are the revenues disposed of?_____

_____

_____

_____

(b) What reserve funds are provided for and what are the requirements of each? What is the amount in each at present?

Name of reserve fund	*Requirements*	*Present Amount*
_____	_____	$_____
_____	_____	$_____
_____	_____	$_____
_____	_____	$_____
_____	_____	$_____

(c) What is the covenant or legal requirement respecting the rates to be charged for the services rendered?_____

_____

_____

(d) What are the provisions for issuance of additional bonds?_____

_____

_____

_____

(e) Is the preparation of an annual budget required? Yes_____ No_____
If "Yes", is a public hearing provided for? Yes_____ No_____

(f) Is issuer required to make public statement regularly re earnings? Yes_____ No_____
If "Yes", how often? _____

(g) What insurance is required?
Type _____ Amount $_____
Type _____ Amount $_____
Type _____ Amount $_____

Name of corporate trustee, if any_____

Name of consulting engineer(s), if any_____

Name of the attorney(s) approving the legality of the issue_____

Has the facility defaulted during the past 20 years for a period of 60 days or more in the payment of either principal or interest of any of its bonds or notes? Yes_____ No_____ If "Yes", give full particulars in a separate statement, including terms of settlement.

Is there a competitive system in operation? Yes_____ No_____ If "Yes" give, in a separate statement, the system's name, location and extent of its operations.

Are any contributions to be made to or received from any political body? Yes_____ No_____ If "Yes", give details.

_____

Please furnish information, in a separate statement, regarding the economic background and financial condition of the issuing governmental body—location and operation; also general character of industries and transportation facilities in the area served.

Signed _____

Official Title _____

Date_____

4-28-48

R-112

Condensed Report of Revenue and Expenditures of the

_____

(Insert name of issuing political body)

FOR THE PERIODS SHOWN

	Fiscal Year ended ____	*Same period 1 year ago*	*Same period 2 years ago*
1. Operating Revenue	$	$	$
2. Nonoperating Revenue			
3. Total Gross Revenue	$	$	$
4. Expenditures for Operation & Maintenance (incl. payments for Employees Retirement & Disability Fund)			
5. Other charges, if any, against Gross Revenue			
6. Net Income available for debt service			
7. Interest paid on bonded debt			
8. Principal paid on bonded debt			
(a) Matured			
(b) Called			
9. Other charges against Net Income (specify various funds) *			
(a) _____			
(b) _____			
(c) _____			
(d) _____			
10. Amount available for retirement of debt by call			
11. Surplus (state to what uses surplus has been or may be put)			
_____			
12. Total amount of bonds issued (original & subsequent)			
13. Bonded debt at end of period (also show below)			
(a) Bank loans at end of period			
(b) Other unfunded debt at end of period			
14. Principal & Interest on bonded debt next fiscal year			
15. Maximum Principal & Interest requirement on present debt in any future fiscal year			
16. Total amount accumulated in reserve funds** (name & amount)			
_____			
_____			
_____			
_____			
17. Present book value of plant and equipment after depreciation			
18. Estimated average daily water supply (in gallons)			
19. Average daily water consumption (in gallons)			
20. Water storage capacity (in gallons)			
21. Number of customers at end of period—Residential			
Commercial			
Industrial			
All Others			
22. Gallons water consumed per customer—Residential			
Commercial			
Industrial			
All Others			

*What method of depreciation is used? _____

*What disposition is made of revenue in these funds? _____

**How are reserve funds invested? _____

(See reverse side)

Latest Balance Sheet

As of_____, _____, 19____

(Insert or attach copy)

Are there any contingent liabilities not shown in the balance sheet? Yes_____ No_____

If "Yes", explain. _____

Name and address of auditor preparing the annual audit. _____

Is the auditor an independent auditor? Yes_____ No_____

Is sewer service charge based on amount of water metered? Yes_____ No_____ If not what is the base?

Does the sewer charge appear on water bill? Yes_____ No_____

May water and sewer charges be paid separately? Yes_____ No_____ If "Yes", explain_____

If sewer charge is not paid, does it become a lien on real property? _____

May past due water bills become a lien on the property? _____

What is the source of water supply? _____

Does the system contain a sewage treatment plant? _____

Other Pertinent Data or Comments

_____

_____

_____

_____

_____

_____

_____

_____

_____

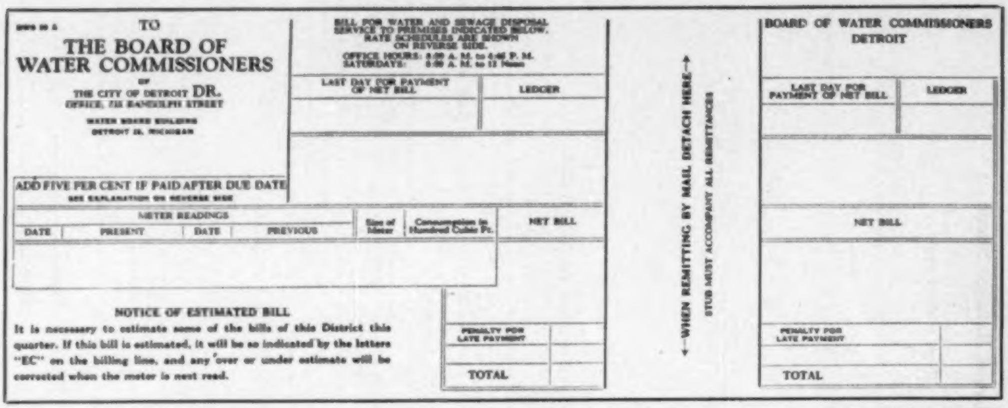
_____

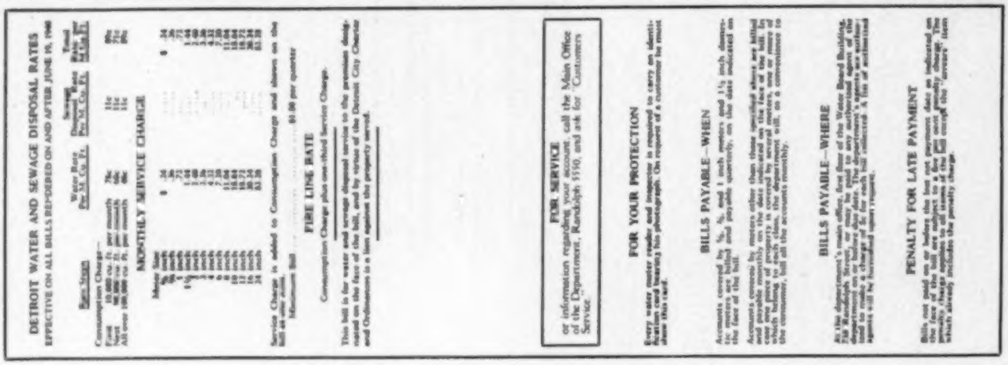
Signed_____

Official Title_____

Date_____

1-10-50





   2. Volunteers
   3. Appoint publicity director

B. Report on investigations
   1. Engineer's report
   2. Financing methods (advice obtained from bond attorneys)
   3. Comparable conditions in other cities. How remedied?

C. Publicity
   1. Newspaper articles. Full details given to press; cooperation obtained in interest of public welfare
   2. Advertisements—if election to be held, present final conclusive arguments immediately preceding election day
   3. Booklets and pamphlets—simple, direct statements

D. Canvassing
   1. Individual calls by volunteers
   2. Endorsements by prominent citizens

E. Local Organizations
   1. Obtain support of local groups
      a. Business
      b. Professional
      c. Chamber of Commerce
      d. Women's Organizations
      e. Civic Clubs
      f. Schools, etc.

F. Lectures and radio talks
   1. By city officials
      a. Engineers
      b. Attorneys
      c. Volunteer citizens

G. Displays
   1. Posters in store windows
   2. Posters in homes

The campaign should enlighten the public on the need for the project, but should not be directed exclusively to the citizens of the community. Advantage can be taken of a wider sphere of influence and facts developed during the campaign to reveal the capacity of the sewage works to earn its own way on a businesslike basis. This provides an opportunity to inform the residents of the community of the indispensable services they receive at nominal cost.

The campaign can also be used to build up the character of the municipality. The percentage of home ownership, the healthy growth of local service organizations, church attendance, the use of public libraries and community facilities are all indicative of the character of the community.

Revenue Bond Ordinance

If bond counsel has not been engaged, early employment of expert legal advice is highly recommended. Bond counsel and financial consultants should work in close harmony through all steps in the procedure.

In the event of any challenge on a point of procedure or the possible contest on the validity of an ordinance bond counsel is better able to defend the action if thoroughly familiar with all on-the-spot discussions. Particular attention should be given to the drafting of the bond ordinance. Some typical provisions of a Revenue bond ordinance are given below, but for a more detailed discussion the reader would do well to refer to a paper entitled "Financing Through Revenue Bonds" published by the National Institute of Municipal Law Officers as Report No. 107.

Typical provisions of a revenue bond ordinance are illustrated in the following outline:

ORDINANCE NO. ....

Title:

An Ordinance Authorizing the Construction and Operation of a Sewage Treatment and Disposal System for the City of..................: pursuant to the act of the..................legislature known as the..................act of.......................... and further under the act of the...................... legislature known as the..............................act to provide for the financing of construction operation, improvements, extensions and betterments by the issuance of Sewer Revenue Bonds, payable solely from sewer service charges and revenue derived from the operation of the system and to provide funds for paying all or a part of the cost of such system; providing that such Sewer Revenue Bonds shall not constitute a debt of the City or a pledge of its full faith and credit; requiring connections with sanitary sewers to be served by such system; providing for the imposition and collection of rates, fees and charges for use of services and facilities of the system and for the creation of certain special funds; pledging the net revenues of the system to the payment of principal and interest obligations on such Sewer Revenue Bonds and setting forth the rights and remedies of the holders of such bonds.

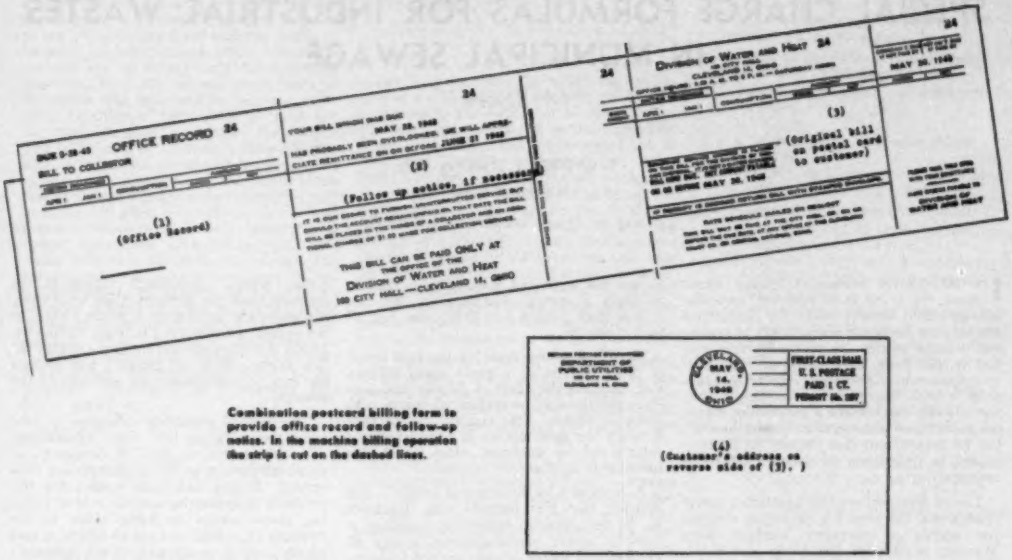
Resolution:

(Set forth in detail necessity for project, its extent, purpose, authority to act, also descriptive details of project with enumeration of all facilities.)

Ordinance Proper:

Article I—(Detailed definitions)

Article II—(Set out in detail authority for issue, form and provision for registration of bonds. Accurate description and designation of bonds should be given together with interest provisions and denomination of bonds. There should be a section devoted to transfer provisions stating specifically how title to any bond shall pass. It is especially important to



Combination postcard billing form to provide office record and follow-up notice. In the machine billing operation the strip is cut on the dashed lines.

provide for negotiability in appropriate language declaring the bonds negotiable with the same incidents as other similar instruments payable to bearer. Place of payment should be stated which for convenience should be an established financial center.)

Other sections will provide for:

1. Reserve Fund.
2. Amortization.
3. Notice and Right of Redemption and Redemption Price.
4. Issuance of duplicate in case of loss.
5. Covenants.
6. Remedies.

Consultants Are Important

The financial consultant will study special phases of the finance problems such as timing of the issue, coupon rates, manner of issue and many other similar details on which one familiar with municipal finance will have special knowledge.

Many of the steps necessary to be taken in planning for the financing of sewage works will necessarily be taken at the same time. The selection of the consulting engineer, for example, is an important matter to be decided as early as possible. His knowledge of the project requirements and his study of rate structures, more important now than ever before, will enable him to contribute valuable information desired by both legal counsel and financial consultant. Municipal officials should not overlook the tremendous advantage of conferences throughout the proceedings from beginning to end which include bond counsel, financial consultant and engineer. In this manner common problems can be resolved to the ultimate benefit of the municipality.

When it becomes necessary to decide upon the type of bonds and the manner in which they should be issued and sold, reliance should be placed in the advice of bond counsel and financial consultant.

The bond attorney in company with local officials should be prepared to discuss the proposed bond issue with bond dealers in the large financial centers. Ordinarily it is not possible to finance a large project entirely through local dealers.

After all details have been ironed out the bonds will be ordered issued in accordance with the plan decided upon and in the order and amount specified. At this point also the educational campaign will be of material help in smoothing the path of the steps that follow. A prospectus will have been prepared, giving a clear outline of local finances, prior obligations, assessed valuation, number of users and estimated income. If the job is well done and confidence has been created in the reports of the engineer and others connected with various phases of the proposed improvement, the prospectus will be well received by investors. It should be at once apparent from all that has been said that every step must be given careful thought and decisions made only after thorough study and deliberation. This groundwork all along the way is of extreme importance to the municipality and cannot be overemphasized.

Billing and Collection

Following the successful financing and construction of the improvement will come the problems of billing and collecting accounts. Considerable work has been done and reports of a Committee of the American Water Works Assn. studying this subject have been published in the Journal of that Association.

The most convenient basis is a joint billing of water and sewer accounts where possible. This presupposes a metered water supply and a charge for sewer service based primarily on water consumption. The most common practice is to show the charge for water and sewer service charge as separate items on the same bill. Prompt payment of the bill is often encouraged by discount privileges which can only be taken if both items are paid.

It is essential for the maintenance of good credit that a good follow-up system be adopted to prevent delinquencies. Usually a post card reminder is all that is necessary. If it becomes necessary to apply legal sanctions to enforce payment there is authority for the water shut-off device. In a survey of numerous municipalities made by the Joint Committee of the Section of Municipal Law of the American Bar Assn. and the American Society of Civil Engineers, previously referred to, it appears that the threat of water shut-off is the most effective means of enforcing payment. As a practical matter it is seldom necessary to invoke this sanction.

The methods of enforcing payment of water and sewage charges are discussed in detail in the report of the Joint Committee previously mentioned. The growing acceptance of the revenue bond method of financing sewage works will encourage municipal officials to develop information based upon experience. The exchange of knowledge guided by reports of intensive study by those vitally interested will result in healthy growth and businesslike management of the two most essential public services affecting the health and welfare of large and small communities throughout the United States.

SPECIAL CHARGE FORMULAS FOR INDUSTRIAL WASTES IN MUNICIPAL SEWAGE

(A Review)

By GEORGE E. SYMONS, Ph.D.
Managing Editor
Water & Sewage Works, New York City

IN MODERN municipal sewage treatment, the trend is to establish formulas for equitable service rates for industries discharging excessive waste loads to municipal sewage works. In reviewing this subject in the June, 1946, issue of *Industrial & Engineering Chemistry*, Harold R. Murdock[1] said, "the rental of municipal sewage systems can become a convenient means for industry to dispose of its liquid wastes", but he pointed out that "equity to all concerned in disposition of waste products is essential."

The earliest writers recommending sewer rentals and the need for providing charges for wastes of excessive strength were Marsten of Metcalf and Eddy, and F. H. Waring of the Ohio State Health Department. The earliest agreements toward this end were those wherein industry has paid part of the construction costs of sewage treatment plants handling the wastes. Perhaps the most notable example was the city of Cedar Rapids, Iowa. Most of the agreements of this type have been based on yearly or negotiated charges.

Buffalo Formula

In February, 1943, a new type of service charge was introduced at Buffalo, N.Y. This was the "Buffalo Formula" in which industry was charged for excessive wastes on the basis of volume, and concentration of waste. As reported by Symons and Crane in the Mar., 1944, issue of *Water Works and Sewerage*[2], the following formula is used for calculating the charge applied:

$$R = FP_c(C - N_c) + FP_s(S - N_s)$$

where R = rate of special charge, cents/1,000 cu. ft. of waste volume.

F = factor for converting the ppm. to lb./1,000 cu. ft.

P_c = contract price of chlorine, cents/lb.

C = concentration of chlorine demand of waste, ppm.

N_c = normal dry weather chlorine demand of raw sewage, ppm. of sewage received at treatment works.

P_s = cost in cents of chemicals for sludge conditioning, and of power for solids disposal resulting from 1 lb. of suspended solids received in raw sewage at treatment works.

S = concentration of suspended solids in waste, ppm.

N_s = normal grit-free suspended solids of raw sewage as received at treatment works, ppm.

The factor P_c may vary from year to year according to the contract price for chlorine, and the factor P_s may vary according to the price of chemicals and power involved in the disposal of solids, as determined from operations for the previous year or previous two years. The factors C and S may be established by analysis (periodic or otherwise) to obtain average concentrations to be applied for any agreed length of time.

Average sewage results at Buffalo are 5.6 ppm. chlorine demand and 157 ppm. suspended solids. The special charge for 1000 cubic feet of waste amounts to 0.136 cent for each ppm. chlorine demand and 0.00305 cent for each ppm. suspended solids determined by the sewage analysis. It has not appeared economically feasible to apply a special charge when the rate is less than 1 cent per 1000 cubic feet of waste volume.

The "Buffalo Formula" is the final result of simplification of a great many factors. For example, the effect of dilution and possible reactions of an industrial waste with sewage during the course of passage through the interceptors is considered and determined by analyses, after which the formula is applied.

A reference to the original article[2] will indicate that this formula was developed to fit the specific conditions existing at Buffalo, where prechlorination, sludge digestion, and sludge dewatering and incineration only are practiced. The "Buffalo Formula" makes no charge for the volume of the waste per se. The rate is based per thousand cubic feet of volume, but is a rate only for chlorine demand and suspended solids above the normal average load existing in the sewage. Inasmuch as the sewer rental system in Buffalo charges according to volume, it was simpler to prepare this formula for charge on the volume basis.

The application of these charges has been successful so far in Buffalo. When questions arise, cooperative and friendly negotiations have solved the problem.

New Brunswick, N. J.

In February, 1944, New Brunswick, N. J., passed an ordinance based on the premise that all wastes should be treated at the municipal plant without pretreatment by industry. The ordinance stated: "The charges for factory effluents or industrial wastes discharged into the city sewers or tributaries thereof shall be fixed and determined according to flow, suspended solids, and chlorine demand, according to the following schedule of rates: $22.00 per million gallons, $5.00 per ton of sludge, and $5.00 per 100-pound chlorine demand." Chester Paulus[3], mayor of New Brunswick, reported in July, 1944, that "if industrialists are willing and do cooperate, most industrial wastes can be handled in adequately designed sewage treatment plants constructed for the treatment of domestic sewage; but in this cooperation the industrialists must be prepared to pay their full share of the cost of the plant enlargement and plant operation."

The Wright Formulas

Another approach to this matter of industrial waste formulas was proposed by Dr. S. R. Wright[4], Head of the Civil Engineering Dept. of the Univ. of Texas. Dr. Wright wrote as follows:

"There are two methods of handling charges for industrial wastes. One method places the responsibility of pretreatment of sewage on the industry so that the industrial wastes entering the city's system will come within prescribed standards of strength, and the industry then would pay for sewerage service on a volume basis at the regular rate charged to other customers. Under the other method the city receives the raw sewage from the industry and adjusts the rate to compensate for strength of the sewage.

The method requiring industries to pretreat their wastes has many advantages. The city is able to place all customers on an equal footing as far as charges are concerned. Strong industrial wastes are by-products of industries and the cost of treating these wastes to bring them to the strength of normal sewage should be a part of the cost of production of the industry's finished product. Shock loads from strong industrial wastes may upset the bacterial action in the sewage treatment plant. While such a requirement of pretreatment by industry of its wastes would be very desirable from the standpoint of the city, it is not always practical. The wastes from certain industries might be slightly stronger than the prescribed standard of normal sewage but would not be sufficient to justify a treatment plant. In other industries it may be undesirable or impossible to place the pretreatment facilities at the plant site. The owners of large plants often are influential in local politics and may make it difficult for the local city administration to enforce such regulation.

"If pretreatment of industrial wastes is not required of industries, some adjustment should be made in the rate schedule to compensate for the concentration of the sewage.

" . . . Wastes from establishments that contribute wastes of approximately the same concentration as sanitary sewage are not usually classed as industrial wastes. . . . It is well to provide that an industry must make application for sewerage service and in many cases the regular sewage rate can be applied; but for those industries with wastes of an abnormal character, a special study of volume and concentration can be made and an agreement can be reached with the industry relative to the charges before service is granted."

Where primary treatment only is afforded, Dr. Wright recommends that the basis of special charge be suspended solids, and if chlorination is used, suspended solids and chlorine demand should be the basis of charge, while if complete treatment is afforded, then the basis of charge should be suspended solids and B.O.D.

Dr. Wright assumes that 50 per cent of the suspended solids will be removed in primary treatment alone. "In the case of industrial waste, since the added cost of operation, due to the concentration is the added cost of treatment, it will be necessary to estimate the ratio of the annual cost of operating the treatment plant to the total

amount cost of operating the entire sewage works system. If the charges are intended to pay all costs, the fixed charges should be included in both annual costs, but if the charges are to defray only the operating expenses, then the annual costs used to determine this ratio will be only the operating expenses of the treatment plant and the total operating expense of the system. The added cost of treating a thousand gallons of industrial waste will be due to the excess solids contained by the waste above that of normal sewage which ordinarily will be about 150 parts per million. But where primary treatment is the only treatment involved, about half of the total suspended solids will pass off with the effluent and will not add to the cost of treatment. When charges are to be determined for a given industry several tests for suspended solids should be made on the industrial waste in question. With the above information, a factor to multiply the regular volume rate by, to adjust for concentration, can be determined. Expressed as a formula this factor would be:

Formula:

$$F = 1 + \frac{.5R\ (S - 150)}{150}, \text{ or}$$

$$F = 1 + \frac{R\ (S - 150)}{300}$$

"Where F is a factor by which the regular volume rate is multiplied, R is the ratio of the annual cost of treatment to the total annual cost of the entire system, and S is the suspended solids, expressed in parts per million by weight, in the industrial waste in question. An example will illustrate. Assume that the cost of the primary treatment is $20,000 per year, and that the annual cost of operating the entire system is $50,000. Then R in the above formula becomes 0.4. One industry contributes a waste containing a suspended solids content of 750 ppm. Substituting in the above formula, F becomes 1.8. In fixing the charge for this industry the regular rate per thousand gallons should then be multiplied by 1.8, or in other words, this industry should pay 1.8 times as much per unit volume as a user of the system who contributes only domestic sewage."

This formula works equally well and equitably for industries whose suspended solids input is far below the average. Dr. Wright suggests that where the factor F is between 0.9 and 1.1 (i.e. suspended solids of 75 to 225 ppm.) it should not be necessary to make any adjustment in the regular sewage rate.

When complete treatment is afforded, Dr. Wright assumes the average B.O.D. of domestic sewage to be 200 ppm. and adds another term to the formula to take into account the secondary treatment in the following manner: "The added cost due to a heavy organic content would be

$$\frac{\text{B.O.D.} - 200}{200}$$

times the normal organic load. But since approximately one-third of the B.O.D. is usually removed in the primary treatment the added cost due to the extra load on the secondary treatment is due to only two-thirds of the total organic load in the industrial waste. Therefore, the factor by which the volume rate must be multiplied where complete treatment is involved may be expressed as:

$$F = 1 + \frac{R\ (S - 150)}{300} + \frac{2R\ (\text{B.O.D.} - 200)}{3 \times 200}$$

Which can be simplified to:

$$F = \frac{300 + R[(S - 150) + (\text{B.O.D.} - 200)]}{300}$$

where F is the factor by which the volume rate is multiplied, R is the ratio of cost of treatment to the total cost of operation of the sewerage system, S is the suspended solids in the industrial wastes expressed as ppm. and B.O.D. represents the 5-day B.O.D. in ppm. of the industrial waste. As an example, let R be assumed to be 0.6. A local packing house discharges a strong solid content of 1,000 ppm. and a 5-day B.O.D. of 3,000 ppm. Under these circumstances F would be 8.3 times the unit rate for ordinary domestic sewage. On the other hand, an industry similar to the one quoted in the preceding example which discharges relatively clear water into the sewers could receive an adjustment in its rate schedule."

In this case too, Dr. Wright recommends no adjustment of the normal rate when the factor F is between 0.9 and 1.1; under which condition the B.O.D. could vary 100 ppm. or more without affecting the actual rate charged.

Dr. Wright concluded with the thought that it is desirable to base industrial sewage rates on volume of water actually discharged to the sewers, and to make the adjustment on the concentration basis even though some other basis of charge is used for the domestic sewage.

The formulas suggested by Dr. Wright are a variation of the principle adopted in the Buffalo Formula, namely that industry should pay an extra service charge for any load it imposes on the treatment plant over and above the load normally to be expected in the same volume of domestic waste.

California Formula

There exists a very excellent report on this subject prepared by the 1945 Committee on Industrial Wastes of the California Sewage Works Association. That report was reprinted on page 503 in the May 1946 issue of *Sewage Works Journal*.(9)

For persons who are faced with the problem of handling industrial wastes in municipalities we heartily recommend a thorough study of that California report. That report includes a survey of methods used in handling industrial wastes, a listing of factors to be evaluated in arriving at a charge or a basis of charge for handling industrial wastes, as well as a discussion of public policy and examples of existing formula or ordinances for charges. In addition, the report includes a thorough discussion of the various factors affecting the following: Chambers of commerce, industrial management, sewage works operations, local government agencies, state agencies, and sanitary engineers and consultants.

Specifically that report lists the following: "Factors to be Evaluated in Arriving at a Charge, or Basis of a Charge, for Handling Industrial Wastes."

"A. Type of sewage treatment plant or disposal method used in a given municipality:
   1. Discharge into stream—dilution only.
   2. Preliminary treatment—screening, de-gritting, de-greasing.
   3. Primary treatment—sedimentation and digestion.
   4. Secondary treatment:
      (1) Chemical precipitation.
      (2) Biological treatment—trickling filters.
      (3) Biological treatment—activated sludge.

"B. Designed volume of plant and the present percentage of volume used in treating the city sewage.

"C. Capacity available in plant design for absorbing industrial wastes.

"D. Type and character of wastes to be handled:
   1. Volume.
   2. Suspended or settleable solids.
   3. B.O.D.
   4. Toxic or destructive material or inhibitive elements present.

"E. Policy of city as regards industry:
   1. Whether city is obligated or committed to accept wastes.
   2. Whether they feel it expedient or politic to handle the wastes of certain plants.
   3. Whether the present plant will handle any excess capacity or whether new units or additional treatment will be required if wastes are included.
   4. Amount of taxes contributed by industries to general city funds.

"F. Basis of charges for handling industrial wastes:
   1. Charging for entire load contributed by industrial plant on basis of—
      (1) Volume.
      (2) Suspended or settleable solids.
      (3) B.O.D.
      (4) Chlorine demand.
   2. Charging for excess loads contributed by industry in relation to composition of normal sewage of city:
      (1) Excess volume.
      (2) Excess suspended or settleable solids.
      (3) Excess B.O.D.
      (4) Excess chlorine demand.

"G. Fixed charges:
   1. Whether industrial plants should pay proportional charges of operation, such as interest on plant investment, amortization, obsolescence, etc.

"H. Charges for maintenance:
   1. Whether the industry shall be charged for its proportional share of maintenance charges on large sewerage systems, where these are recorded separately from sewage treatment plant costs.

"I. Initial cost of plant:
   1. Whether, in case an existing sewage treatment plant accepts industrial waste, the industry should be charged for its proportional part of the initial cost of the plant, on the basis of volume or other constituent contributed.
   2. Whether industry should pay the entire cost of new units or for additional degrees of treatment required to treat its wastes, or pay only its proportional part as represented by its ratio of volume or load to the city's volume or load.

"J. Rebate or reduction for taxes paid to city by industry:
   1. Whether the total amount of taxes paid by an industry should be deducted from the total of any charge arrived at for handling its wastes.
   2. Whether only the proportional part of the taxes paid by an industry as represented by the proportion of the city taxes used for sewage treatment and maintenance shall be deducted from the total of any charge arrived at for industry.

"K. Adjustment for beneficial wastes discharged by an industry. In some

cases an industry may discharge a waste which would:

1. Tend to flush sluggish sewers and keep them from clogging or building up sludge banks.
2. Neutralize wastes contributed by other industries to the point where the flow would then not be harmful to structures or inhibitive to processes.
3. Precipitate sulfides from the sewage.

"L. Adoption of a standard of maximum strength of sewage to be admitted to sewers and treatment plants:

1. Whether a maximum limit of suspended solids, settleable solids, B.O.D., etc., shall be set up by state or local agencies and an industry required to pay for all in excess of that or,
2. With a maximum demand set up for the above constituents, whether an industry can build its own treatment plant and reduce its wastes to the maximum allowable in the city standard and thus avoid payment of additional charges to the city for handling its wastes in the public sewers and treatment plant.

"M. Consideration of charges to an industry that receives no other benefits from a city but pays large taxes. In some cases the taxes paid by an industry (*i.e.*, oil field wastes) might well be more than any charge that might be made for handling those wastes in a city plant. This would result in the city treating the wastes free if all taxes paid were rebated against the handling charge.

"N. Consideration that industries which have mutually neutralizing wastes join together in joint districts to consolidate their several wastes and turn out an effluent within the maximum limit set, thus avoiding any charges.

"O. Extent of requirement for pretreatment of any or all wastes before discharge into a public system.

"P. Devising of a basic formula taking into account the various elements which can be used by any particular municipality in adjudging the charges to be made according to the polluting or disturbing elements contributed by any of its industries.

"Q. Recommendations for an enabling act by state legislature to permit any particular city, county, or other local governmental agency, to set up regulations and devise formulae for charging for industrial waste treatment.

"R. Recommendations that study of industrial wastes and basis of handling by city, county, or other local governmental agency, be made by engineers engaged in and familiar with this phase of engineering.

"S. Recommendations that conferences be held between municipal officials, industrial plant management and engineers to arrive at a logical and satisfactory basis of charges."

The California Report suggests definite controls and contracts in connection with industrial waste treatment by municipalities, as follows:

"In order to have any control over industrial waste discharged into a public sewer, an application for permit should be required from all industrial users or prospective users of the sewage disposal facilities, showing the chemical composition and other characteristics of its wastes. Such application should include the following items:

1. Volume. Normal uniform flow, peak flow, and facilities for retention of flow to level off peak loads.
2. Suspended or settleable solids.
3. B.O.D.
4. Chlorine demand.
5. Temperature.
6. pH.
7. Oil.
8. Grease.
9. Sulfides.
10. Maximum size of solid particles.
11. Chemical contents (constituents which might affect the sewer lines or treatment plant through action on concrete or steel, inhibition of bacterial processes, etc.).
12. Odors or other nuisances.
13. New facilities required.

"A definite contract should be entered into between the governmental agency and the industry based upon one of the following policies:

1. Handle all wastes without charge. This may amount to an actual subsidy of the industry by the community.
2. Charge the industry according to the unit cost of handling the waste, based on cost per million gallons, pounds of B.O.D. or dry weight of solids.
3. Charge the industry for the extra cost of treating the industrial waste, *i.e.*, the extra cost above that of treating the sewage of domestic quality.
4. Charge the industry for treating its industrial waste but take into account all taxes paid exclusive of industry. This can be computed according to the following formula suggested by the committee:

T = all taxes paid to city exclusive of industry.
t = taxes paid by industry.
S = cost of operating sewerage works before industry contributes, paid by T.
s = industry's share of sewage works operation cost, without industrial wastes added, paid by t.

$$s = Ts/T$$

M = cost of operating sewage works with industrial waste added.
K = extra cost assessed to industry.

Then $K = M - (S + s) = M - S(1 + t/T)$."

Belleville, Ill.

In developing sewer rental charges for Belleville, Ill., George S. Russell, Cons. Engr. of St. Louis, wrote as follows:[6]

"In the past, for other communities, sewerage rate ordinances have been based on one of three methods.

"The first method is to base the service charges, or sewer rentals, on volume alone. This has been accomplished by charging on the basis of the volume of water used where water is metered, or by employing a rate per fixture of different types which could be proportioned on water use.

"The second method which has been used, bases the charge on strength alone. One basis for accomplishing this has been what is known as the "equivalent population" method. This method is usually predicated on the number of pounds of B.O.D. discharged to the sewer converted to equivalent population. In this computation the figure usually employed as representing the waste from one person is 0.17 lbs. of B.O.D. per day.

"The third method represents a consolidation of the first two, basing the rental charge on a combination of volume and strength of sewage. The City of Akron has recently adopted such an ordinance. It seemed to the officials of Belleville that such a method was the logical one, and the engineers were instructed to develop such a rate structure, comparing the results obtained by this method, with payments to be made under other methods.

"The cost of the improvements to be made at Belleville will be approximately $1,200,000. Of this amount, 60% can be charged to provisions to handle volumetric flow, and 40% as being chargeable to strength of the sewage, or B.O.D.

"If the B.O.D. of *all* sewage, domestic and industrial, were approximately the same then the volumetric method could be used without any inconsistency. As the average B.O.D. of domestic sewage in Belleville was close to 200 ppm., it was decided to establish rates on the basis of the water used alone, as long as the B.O.D. of the sewage averaged not more than 200 ppm., and to make an additional charge for wastes which have a B.O.D. greater than 200 ppm.

Using the figure of average domestic sewage strength at 200 ppm., and per cent of plant cost dependent on B.O.D. as 40%, it is apparent that the *additional* charge for B.O.D. in excess of 200 ppm., should be 40/200% or 1/5 of one per cent. It was also determined that in order to take care of operation and maintenance, and provide net earnings greater than 150% of that required for debt service, the sewer rental charge must be predicated on 60% of the existing water rates.

The "Belleville Formula" therefore becomes:

$$R = R_B + [0.002 \times (B.O.D. - 200)]R_B$$

Where
R = Rate per 100 cu. ft.
R_B = Basic rate per 100 cu. ft.
B.O.D. = ppm. B.O.D. of waste

"These determinations produced the following proposed rate structure:

Monthly Rates

	Cu. Ft.	Rate Per 100 Cu. Ft.
First	13,000	$ 0.20
Next	13,000	0.15
Next	27,000	0.125
Next	27,000	0.096
Next	54,500	0.072
All Over	134,000	0.066

Additional charge—for every part per million of biochemical oxygen demand that the industrial waste exceeds 200, add one-fifth (1/5) of one per cent."

In order to "sell" this program to the several industries, Mr. Russell reduced these sewage handling costs to costs per unit of industrial production. This gave each industry tangible figures which it could use in revising its cost of production. For example, the costs were calculated as follows:

Beer—7.2 cents per bbl.
Packing House—16.0 cents per hog.
Laundry—21.0 cents per 100 lb.
Catsup—0.33 cents per case.
Spaghetti—1.2 cents per case.

Allegheny County Formula

Another approach to a formula for charging industry was developed by Laboon, et al[7] as set forth below.

"The recommended schedule of rates follows:

The first 100,000 gal. per quarter @ 18c per 1,000 gal.

The next 1,000,000 gal. per quarter @ 12c per 1,000 gal.

The next 3,250,000 gal. per quarter @ 09c per 1,000 gal.

For all over 3,350,000 gal. per quarter @ 07c per 1,000 gal.

"It is provided however, that no bill would be rendered for less than 50c per month. No discounts would be allowed at the start. Flat rate charges shall be equivalent to 85% of the present flat rate charge for water usage now in effect in the City of Pittsburgh.

"Under the basic rate schedule as designed and offered herein, 17% of all domestic customers would pay 50c per month; 26% would pay between 50c and 75c per month; 22% would pay between 75c and $1.00 per month; 33% would pay between $1.00 and $2.00 per month and 2% would pay more than $2.00 per month.

"A special study has been made of the additional cost of treating excessive volumes of industrial wastes as measured in terms of total suspended solids, biochemical oxygen demand and chlorine demand in excess of normal requirements, based on primary treatment. An extra charge will be made to commercial and industrial establishments when the suspended solids are greater than 275 parts per million and the biochemical oxygen demand greater than 300 parts per million. The proposed formula on which the excess charge will be based is as follows:

$$F = 1 + R\left[\frac{0.75(S_1 - S_a)}{S_a} + \frac{0.25(B_1 - B_a)}{B_a}\right]$$

Where,

F = Factor to be applied to basic rate.

R = Ratio of Quality Cost to Total Annual Cost = 0.15.

S_1 = Suspended Solids of Sewage from particular industry in ppm.

S_a = Average Suspended Solids of all sewage = 275 ppm.

B_1 = B.O.D. of sewage from particular industry in ppm.

B_a = Average B.O.D. of all sewage = 300 ppm.

"The increase in cost on this basis is predicated on the actual treatment costs of the excessive volumes, suspended solids and biochemical oxygen demand. The charge is nominal. As an example, on the basis of a suspended solids content of 500 parts per million and a biochemical oxygen demand of 500 parts per million, the additional charge would be 11.7% of the total bill.

"An additional charge will also be made for treatment of wastes possessing an excessive chlorine demand. Chlorination of the effluent of the sewage treatment plant will be a requirement of the Sanitary Water Board. The chlorine demand of the central plant sewage cannot be determined until the plant is in operation and therefore only the rate formula can be given now, as follows:

$$R_c = FP_c(C_1 - C_a)$$

Where,

R_c = Surcharge Rate for Chlorine Demand in cents per thousand gallons.

C_1 = Chlorine Demand of wastes from particular industry in ppm.

C_a = Average Chlorine Demand of all sewage in ppm.

F = Factor for converting ppm. to pounds per thousand gallons = .00835.

P_c = Contract price of chlorine in cents per pound.

This charge likewise is nominal."

In reviewing this subject, one may well conclude with Mr. Murdock's statement that "there appears to be ample justification for combining the disposal of industrial residues with municipal sewage in a common processing plant. The total cost should be lower in such unified operation. When industries have to pay service charges, they will be more inclined to use every means available to reduce the over-all load on processing plants."

Among many others, Dr. Abel Wolman, Prof. of San. Engr., Johns Hopkins University, the writer, and Morris Cohn, Editor, *Sewage Works Engineering*, have all enunciated the principle that industry must bear its fair share of the cost of sewage treatment when its wastes are discharged to the city sewers and that such costs must be considered a legitimate cost of production.

The above formulas and ideas are presented here in hopes that they may serve as a basis for discussion among industry and municipalities faced with this problem. Its solution is not impossible and can be made quite equitable.

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UNDER YOUR GLASS TABLE TOP

By W. D. HATFIELD,
Superintendent
San. Dist. of Decatur, Ill.

In the operation of a water purification or sewage treatment plant the superintendent often finds it necessary to spend considerable time in calculating and arranging pertinent operating data, segregating costs, and planning repairs or rearrangements. Too often this takes more time than he has available. One means of reducing the time spent in these pursuits is to have a well organized office containing the proper reference books, hand books, magazines, and a file of blueprints and other necessary plant data.

Another method of reducing time spent on calculations is to keep certain data, formulas, curves, etc., available on sight. This saves a lot of time lost in looking for these items in reference books or in the plans of the plant. The best place to keep such information handy and always in sight is to put them under a glass top on your desk or work table. This is a convenient and time saving device.

The editors of *Water & Sewage Works* have asked me to write this short item listing what I have "Under My Glass Table Top." What I keep there may not be of interest or application to your plant but it may suggest other material that would be pertinent to your plant.

Cost Accounting Key

In Decatur, for example, in okaying bills for payment, it is my custom to follow the initials with two numbers—the first indicating the appropriation number to which the bill is to be charged, and the second to indicate the proper cost account. Therefore, I keep a list of appropriation and account numbers under the glass table top.

Plant Elevation Data

Another very useful set of information is a list of the elevations of structure, weirs, drains, basement floors, pump suction and discharge and flow levels. Having these data at your finger tips quite often saves a trip to the blueprint files. So helpful is this information, that this same list is posted on the bulletin boards about the plant for convenient use by the foreman and operators. (A flow diagram and profile plot would serve the same purpose.)

Plant Unit Capacities and Gas Measurements

Reference is occasionally necessary to certain plant unit capacities which are hard to keep in mind unless used every day. Therefore, under my table top is a list of cu. ft. or mgd. capacities of settling tanks, digestion tanks, filter beds, activated sludge aeration and settling tanks, pump and meter deliveries.

Our gas production is measured by orifice meters, which, by the way, have numerous advantages over the positive displacement meters so generally used. When gas production gets out of hand, it is easy to change to a large orifice. Under the table top is a list of flow constants for the different orifices we have in stock.

Flow Measurements and Formulas

Flow measurements about the plant are often conveniently made in conduits over weirs, with end contractions or without end contractions. So I keep handy three or four short tabulations of head and flow over such weirs which we frequently use.

Also under the glass are conversion tables of metric to English measurements, power equivalents, geometric equivalents, electrical units, conversion table for Centigrade to Fahrenheit temperatures, a table of proofreader's marks, and a list of atomic weights. In addition, there are conveniently listed formulas for computing detention periods, suspended solids, and B.O.D. loading.

There are many other items, data, and formulas that might be "under your glass table top" such as nomograms for certain calculations, formulas for calculating per cent sludge digestion for volatile matter content, or in water plants, dosage tables for chemical feeder settings, etc. There is, of course, a limit to the size of the table top and the things you personally want under it.

LAYING AND JOINTING SEWER PIPES

By FRED C. PALMER

Engineer Nat'l Sewer Pipe Co., Ltd., Toronto, Ont.

THE question of preventing roots from entering sewer pipes and the annual cost for removing the same, gives considerable concern to sewer departments.

This paper has been drawn from practical experience and experiments, carried out over years, to produce a root-proof and leak-proof joint.

It is also intended to explain, without scientific data and complicated formula, so that the workman, the pipe layer or contractor may be conversant with the many reasons why joints may be defective. The writer is conversant with the many inconveniences and difficulties which confront the contractor and his pipe layer—wet and muddy trenches, threatening storms and cave-in, all of which tend to make difficult the workmanship being carried out.

Roots

Roots will not grow through solid concrete or a solid cement joint, unless there is an opening. They will grow through the very finest hair crack. Roots will not grow through a properly made compound (bitumen joint), but will find their way through a blow-hole or improperly heated compound.

At the tip of a root is a very fine tendril, finer than a human hair. As this tendril grows and reaches a sewer pipe joint, it turns and glides over or under solids, but reaching the finest opening, it enters. Upon entering, the movement of air and flow of sewage draws it in and the warmth of the sewage and its fertilizing properties induce rapid growth. Roots in sewers can be temporarily removed by tools and machines and in some cases their growth can be retarded by the use of chemicals, but they cannot be permanently removed without re-constructing the sewer.

It is not the intention of the writer to deal with the removal of roots from sewers, but rather to suggest means and best methods to prevent their entrance.

Some Types of Joints

The necessity for secure joints is no new problem. Forty years ago engineers introduced the following joints, as shown. These joints are all cast upon the pipes by the pipe manufacturers. (Fig. 1)

Duckett's Patent Stanford Joint (a)

On the spigot and in the socket is cast a bituminous material gradually tapered. Before fitting the pipes together the joints are greased with a mixture of resin and Russian tallow. This makes a tight joint, but it is advisable to finish it off with a seal of cement smoothly trowelled.

Doulton Patent Joint (b)

This is similar to the Stanford with less bitumen and a heavier cement seal. The manufacturer's claims for this joint—imperishable, flexible and can be laid under water.

Tyndale's Patent Double Seal Joint (c)

The convex ring on the spigots makes possible a tighter fit than tapers. The socket of the pipe is deeper and undercut to permit an effective seal with cement.

Button's Patent Joint (d)

These rings are cast with annular grooves. When the pipes are fitted together a grout cement is poured in, which flows and sets between the bitumen rings.

Hassel's Joint (e)

Two cast bitumen rings and two perforations in the socket about three inches apart. After the pipes are fitted together a grout cement is poured into one of the perforations and pouring continues until the grout comes up into the other perforation.

Sykes' Patent Joint (f)

The pipe for this joint is especially manufactured with a flange near the spigot end. The bitumen is moulded in a screw-like thread. Before fitting together a special adhesive cement is spread over the bitumen threads and the pipes are then screwed together. This gives an exceptionally tight joint.

The foregoing joints are shown and described primarily to point out that *expense in jointing becomes secondary to efficiency.*

There are no special joints cast or moulded on sewer pipes by pipe manufacturers in Canada, and the writer is not aware of any joints cast or moulded on sewer pipes in the United States by pipe manufacturers, excepting perhaps special acidware pipe.

There are patent joints, mostly manufactured by chemical companies. These include Patent Rubber Rings, Pre-Cast Compound Joints and Compound for Pouring Joints. These joints require skill and care in their making.

The Rubber or Rubberoid Ring is manfactured to fit the size of pipe required. A cut-back oil is used to aid adhesion, the socket is painted with the cut-back and the ring placed in the socket, then the ring is painted with the cut-back on the inside and on the outside of the spigot and the pipe fitted home. With reasonable care, this is a good joint, but sewer pipes vary in dimensions, such as inside width of socket and outside width of spigot. The variation may be according to the dies of the manufacturer or shrinkage in burning the pipes.

In this, as in any other pre-cast joint, it is necessary to ensure that the pipes used are adaptable to the joint. Some manufacturers supply deeper and wider sockets than others and again some manufacture thicker bodied pipes; and, in burning, sewer pipes vary in shrinkage.

Compound for Either Pre-Cast or Poured Joints

Without going into detail of chemical formulae, Bitumen Jointing Compound consists of approximately 50 per cent asphalt oils and 50 per cent filler, which may be marble dust, slate dust or other aggregate. The heavier the filler, the more difficult it is to hold in suspension; consequently the necessity for repeated stirring during heating and always immediately before dipping out for pouring is evident.

If the compound is left unstirred, the filler sinks to the bottom and on a hot fire will, with the asphalt at the bottom, burn, leaving a residue like coke in the bottom of the pot.

If the compound is poured without having been stirred, the joint will be defective. It will develop blow-holes and through being poured with insufficient filler will overshrink.

When bitumen compound is first used, the pouring temperature as recommended by the manufacturer should be checked with a thermometer so that the workman can become conversant with the appearance and the consistency of the material as it reaches the pouring temperature. Having observed this, he will not need to continuously use the thermometer.

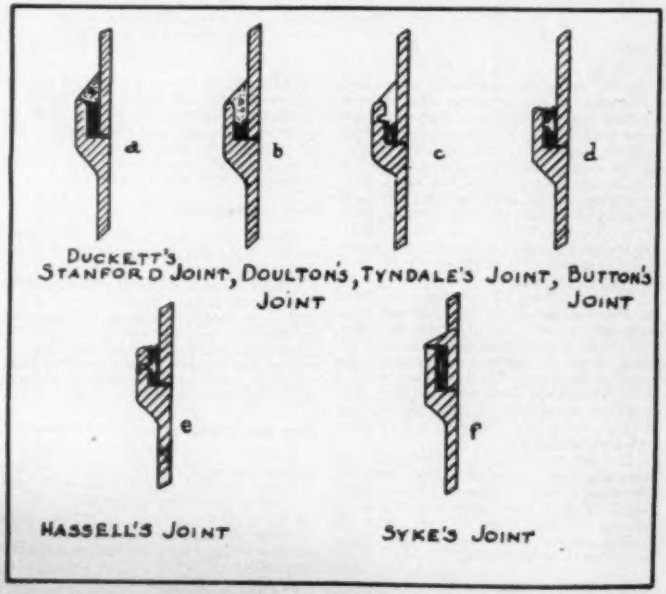

Fig. 1. Special Joints Patented by Engineers

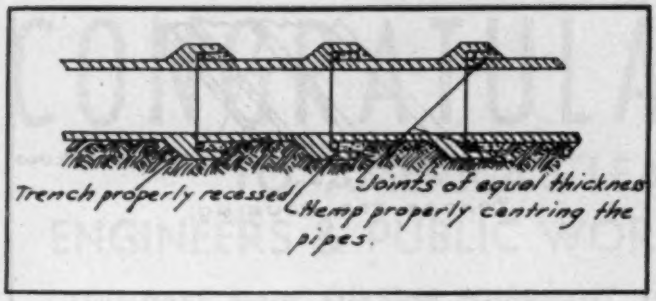

Fig. 2. Correct Sewer Pipe Laying and Jointing

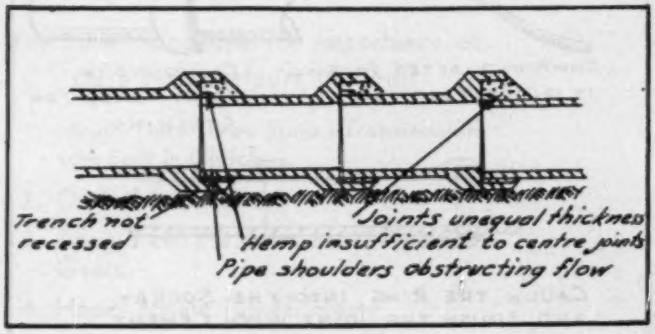

Fig. 3. Defective Sewer Pipe Laying and Jointing

The Trench

Regardless of the fact that the suggested or specified width of trench receives consideration with respect to load on the pipes, a width sufficient to allow proper laying and jointing of the pipe is essential. The use of digging machines and the composition of material to be excavated and weather conditions sometimes prevent the excavating of the trench at a width specified. The trench, naturally, will vary either less or over width.

Four inch to eighteen inch pipe can be straddled by a medium sized man and joints can be made all around from above the socket. Beyond that size, joints have to be made from the sides of the pipe; therefore a satisfactory working width is required. These widths in practice are found to be as follows:

Pipe Size, In.	Trench Width, Ft.	In.	Pipe Size, In.	Trench Width, Ft.	In.
4	1	6	21	3	9
6	1	9	24	4	0
8	2	0	27	4	4
9	2	0	30	4	9
10	2	3	33	5	0
12	2	6	36	5	6
15	2	10	42	6	3
18	3	3			

To ensure good joints the bottom of the trench must be recessed to take the socket of the pipe, as shown in Fig. 2. This is important for two reasons: it gives a bearing along the whole body of the pipe and allows an equal annular space (after the jute or long strand hemp is placed in) to allow a good body of cement or compound all around the jointing space. (Fig. 2)

Laying and Jointing

If the pipe sockets are not recessed, the result will be as shown in Fig. 3. They will be bearing only on socket to socket and the annular space at the bottom of the socket will not be centered sufficiently to hold the required amount of cement or compound. Also, a shoulder causing obstruction as also shown, will be the result.

Jutting

Jute, commercially known as Long Strand M.O. (minimum oiled) Hemp is used either with cement or compound in jointing. This hemp is sold in rope form, ranging from 10 to 35 strands loosely twisted. These strands can be separated according to the thickness required to center up the pipe. Hemp is used for two purposes—to center up the pipes as referred to above, and to prevent cement or compound from entering the inside of the pipes.

It is quite improper to see on sewer construction jobs, the pipes standing socket down along a trench, and one or two strands of hemp twisted around the spigot end ready to be lowered into the trench. The pipe layer should measure the circumference of the pipe he is about to lay by putting this hemp around it, then cutting it in lengths 4 to 6 in. longer than the outside circumference of the pipe. He should pull apart from the rope a sufficient number of strands to fill in thickness (not depth) the annular space between spigot and socket. These strands of hemp should be in the trench with him, not put on the pipe before they are let down.

When ready to fit a pipe into another, the hemp is used to guide the pipe into the socket and is carried into the bottom of the socket with it. The top and sides are then rammed in with a piece of hardwood or caulking tool. It is sometimes specified to dip the hemp in a grout cement first. This does improve the joint, when making cement joints.

The pipe layer holds the strands of hemp rope in one hand and puts the rope across his thigh; he rolls it with the palm of his other hand, which twists the strands together, then holding both ends with one hand he can dip his hemp. Then with an end in each hand he places it under the spigot and guides the pipe into the socket.

Compound Pouring

In pouring compound joints considerable time is saved by ensuring that the running rope is secure and tight in or against the socket, as the liquid when poured is liable to run out of the space. It is well to plaster trench clay around the running rope where it fits against the socket.

The running rope is asbestos, square or round. Round is preferable for sewer pipe. Before using, the rope should be well rubbed with moist clay or graphite to prevent the compound sticking to it.

Compound should be poured slowly in a steady stream and continuously if possible. The weather condition (temperature) should be observed. It is likely in cold weather and particularly with 15 inch pipe and over that the compound will set before flowing to the bottom of the pipe. In this condition, it is well to thaw out or warm the spigots with a lighted rag and kerosene.

Cement Joints

When making cement joints in warm or hot weather, the spigot of the pipe or the whole pipe, should be well wetted, otherwise the moisture in the cement at the joint will be absorbed by the pipe and sufficient moisture will not remain in the jointing cement to allow it to set without cracking.

If neat cement for jointing is used, the joint must be kept moist while setting, particularly in shallow dry trenches.

Providing the pipes when laid and jointed are not immediately disturbed by common faults, such as walking on the pipes, climbing in and out of the trench on the pipes, placing a heavy cement pail roughly on pipe where it lodges on the shoulder of the pipe and leans on the side of the trench, immediate backfilling, knocking joints to pieces and disturbing joints newly made or removing shoring too hastily, the writer has obtained best results from the following:

One part portland cement, two and one-half parts clean, sharp sand. Mix dry, then add sufficient water to dampen, then mix (dampen only). Allow to stand forty-five minutes, then add sufficient water to bring to the consistency for good trowelling. This mix and the time allowed to prehydrate with moisture, eliminates shrinkage and gives excellent adhesion.

Récommended Joint

The writer prefers and recommends the following joint, favorable under any conditions, and as near fool-proof as jointing can possibly be. Use a good jointing compound, such as "G-K," or equal. Place a board or plank on the ground near the melting pot (Fig. 4) and measure the width of the annular space between the spigot and the socket of the size of pipes to be jointed. Place two boards upon the

board or plank already placed and space the two top boards the width of the annular space to be filled and have the two top boards thick enough to be two-thirds the depth of the socket of the pipe, or space your top boards at a distance equal to two-thirds the depth of the socket and as thick as the width, either way will do.

Put a good coat of wash (composed of whitening and water creamy in consistency) with a brush between the space of the boards. This is to keep the compound from sticking to the boards. Put a plug of trench clay in the boards at each end or at a distance equal to the circumference of the pipe or pour several lengths at one pour.

Pour the compound steadily backwards and forwards into the opening, leave it ten minutes to properly set. When one side board is taken away a compound strip, rubber like, has been made.

In warm weather this will be found quite flexible; in cold weather the rings can be kept flexible by laying on a board near the heating pot. Fit it into the joint space and caulk the joint with a piece of hardwood or caulking tool, then cement the balance of the annular space. This will give a waterproof and root-proof joint, with a minimum of labor.

In very wet trenches it is suggested that after caulking in the first ring a second ring be caulked in and the cement eliminated.

The importance of laying and jointing sewer pipes has been recognized by the government of the Province of Ontario, which last year passed a bill enabling all towns and cities to license sewer and drain layers. Men doing this work should be classed as skilled labor. They should be made conversant with the engineers' specifications and the importance of proper laying and jointing should be conveyed to them personally by the engineer or inspector.

They should be made to feel that the importance of their work is appreciated and confidence is placed in their ability to do their best under sometimes very difficult circumstances.

Definite and complete specifications by the engineer and co-operation of the contractor and his pipe layer will eliminate root trouble and infiltration.

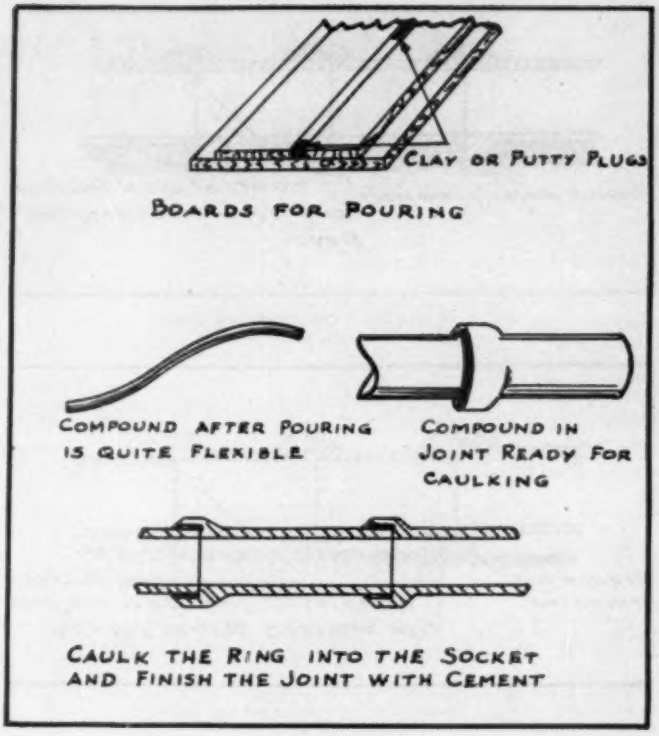
CLAY OR PUTTY PLUGS
BOARDS FOR POURING
COMPOUND AFTER POURING IS QUITE FLEXIBLE
COMPOUND IN JOINT READY FOR CAULKING
CAULK THE RING INTO THE SOCKET AND FINISH THE JOINT WITH CEMENT

Fig. 4. Combination Compound and Cement Joint

CARRYING CAPACITY OF SEWER PIPE—GALLONS PER MINUTE

(Based on "Hydraulic Tables" by Williams & Hazen)

Size, Inches	1" Fall in 100 Feet	2" Fall in 100 Feet	3" Fall in 100 Feet	6" Fall in 100 Feet	9" Fall in 100 Feet	12" Fall in 100 Feet	24" Fall in 100 Feet	36" Fall in 100 Feet
4	....	.....	.....	.....	86	102	149	186
6	....	.....	.....	204	256	297	269	534
8	....	.....	.....	437	539	632	921	1143
9	....	.....	.....	601	749	876	1272	1580
10	....	.....	537	781	974	1138	1653	2055
12	....	730	869	1264	1571	1835	2695	3345
15	....	1242	1556	2275	2835	3300	4790	5950
18	....	2030	2510	3670	4580	5340	7760	9665
24	2985	4325	5390	7810	9740	11380	16530	20550
27	4040	5875	7325	10690	13270	15520	22530	27850
30	5340	7760	8670	14080	17500	20450	29750	37150
36	8740	12600	15640	22700	28350	33000	47900	59500

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EXPERIENCE IN SEWER MAINTENANCE*

By W. H. WISELY

Exec. Secy. and Editor, Federation of Sewage Works Assns.

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Hendryx, Orie G., Supt. Bloomington-Normal (Ill.) San. Dist.
Kilpatrick, J. F., City Engineer, Rolla, Mo.
McNeice, L. G., Engineer, Orillia, Ontario.
Morrow, Ben S., City Engineer, Portland, Ore.
Olney, F. J., Supt. Sewers, Proctor, Vt.
Phelps, Byrl D., Asst. City Engineer, San Diego, Cal.
Semmes, O. J., Jr., City Engineer, Pensacola, Fla.
Sperry, W. A., Supt. Sanitary District, Aurora, Ill.
Steelman, E. S., Mgr., Ocean City (N. J.) Sewer Service.

Of all sewage works operation functions, that of sewer maintenance is usually considered the least pleasant and interesting, yet it is of utmost importance. There is somewhat of an inclination to neglect this essential "chore" in many cases even though the hazards of basement flooding and other effects of faulty sewer operation are appreciated. Good will that has been carefully built up by painstaking public relations activity can be easily destroyed in this way.

Maintenance Program—Records and Inspection

The most important item of equipment in any sewer department is a master map of the system, supplemented by larger scale sectional maps on which are shown important details such as direction of flow, exact manhole locations, sewer sizes and slopes, house connections, etc. Phelps (San Diego) has found that good maps save time and minimize damage to streets and private property, and recommends that all extensions to the system be plotted as made so that the reference maps will always be up-to-date. At Rockville Center, N. Y., Anderson[1] keeps a card index for permanent notes and a log book for daily maintenance notes, both of which are indexed to the sectional maps. The log book is kept by the field crew and records the location of work, conditions found, equipment used and daily costs.

Practice as regards frequency of routine inspection varies widely. Several contributors report that inspections are made only as difficulty arises, while others confine routine inspection to those sewers which have given trouble previously. A number of those reporting this inspection practice indicate that lack of personnel obviates a regular schedule.

Most general inspection practice appears to be as follows: sewers on flat grades or previously troubled by roots—every three months; sewers in which no trouble has been recorded—once to twice yearly; main intercepting sewers—one to four times per month; flush tanks—every month; inverted siphons—one to four times monthly; storm water overflows—during and following heavy rains. Some larger cities maintain a trained inspection crew which is continuously engaged in following a prepared schedule.

Anderson[1] warns that a casual glance into the manhole does not constitute adequate inspection. Steelman (Ocean City) advises inspection of critical sections during peak flows, which advice is substantiated by experience at Urbana-Champaign, Ill., where an 18-inch interceptor appeared to be flowing freely during numerous dry weather observations but was found to be carrying only 25 per cent of capacity when surcharged at the upper end during a very wet season, due to an unusually bad root condition. "Lamping" a section, by looking through the sewer during low flows toward a flashlight (explosion proof) held at the next manhole, is a common method of inspecting lines of 12-inch diameter and larger. Superintendent Case (Merchantville-Pennsauken, N. J.) employs an inspection crew of three men who ascertain the condition of the line by observation at the lower manhole while the line is being flushed or probed with light rods. A change in the color or solids content of the flow will indicate an accumulation. At Birmingham, Mich., the condition of lateral sewers is ascertained whenever an opening is made for a new house service connection.

Where a program of routine cleaning "whether they need it or not" is possible, it is usually correlated with the inspection schedule. At Cimarron, Kan., City Engineer R. R. Crusinberry has developed a schedule of routine cleaning that enables coverage of the entire system every year. At Rockville Centre, where there are 78 miles of sewers, Anderson[1] has planned to clean 26 miles of sewer each year, thus covering the entire system every three years. The work is carried out from March 15 to July 1 and from September to November, totalling about 150 days of the most suitable weather. Work in the business district is done between 4 a.m. and noon to avoid heavy traffic. A similar 3-year schedule for cleaning trunk line sewers, involving work on about 33 miles of sewer per year, has been developed by Superintendent George D. Carpenter at Ithaca, N. Y.

Baltimore, Md., has a well organized plan for continuously servicing the 1,900 miles of sewers and drains in that city.[2] Five crews of three men each are assigned to definite territories and are equipped to clean street inlets and manholes, approximately 1,200 to 1,500 being cleaned weekly. Four crews of five men each are equipped for servicing house connections and small laterals and are constantly engaged in this work. One six-man crew is equipped to work on large sewers and drains. The plan affords continuous maintenance, minimizing complaints and inconvenience to property owners.

Twenty-nine well equipped field crews are able to completely cover the 2,800 miles of sewers in Los Angeles, Cal., twice each year by working according to a systematic plan.[2]

Any routine sewer cleaning program must be arranged to allow for interruptions for emergency calls.

Sewer Maintenance Equipment

The size and type of sewers to be serviced, of course, determine largely the nature of equipment required, but certain items are essential to any efficient crew. Sanitary sewers will usually be troubled mostly by roots and grease, while combined or storm sewers will nearly always accumulate grit and are most likely to receive miscellaneous debris. The equipment carried by the maintenance crew will be most adapted to the character of stoppages anticipated but there must also be equipment for handling the unexpected.

A typical list of essential equipment carried by a full-time, large city maintenance crew working on all types of sewers has been developed from data furnished by the contributors to this article:

Major Equipment

2½ ton truck
Power winch
Portable, manually-operated winch
1,000 feet flexible steel cable
1,000 feet fire hose
600-800 feet flexible rods (power drive desirable)
500 feet interlocking wood sewer rods
Root cutters of assorted sizes
Sewer brushes of assorted sizes
Sand buckets, scoops and drags of assorted sizes
Turbine flushing heads
Steel sewer tapes and heavy wire (for small sewers)
Sewer flushing bags

Minor Equipment

Shovels, picks and mattocks
Assorted wrenches
Hydrant and manhole tools
Flash lights (explosion proof)
Rubber boots, coats and gloves
Buckets and rope

Safety Equipment*

Hydrogen sulfide detector
Carbon monoxide detector
Combustible gas indicator
Wolf safety lamp
Hose mask (double) with safety harness

*From "The Operator's Corner," Sew. Wks. Jour. 14, 410, 1942. Reprinted by permission of the Federation of Sewage Works Associations.

*A combination combustible gas indicator, oxygen deficiency lamp, and toxic gas detector is available on the market.

Safety belts (2 or 3)
Complete first aid kit
Manhole guard rails
Traffic signs and flags
Oil lamps and flares

Commenting on the above list, the power winch for pulling scoops, brushes or buckets may be provided for in several ways. There are several excellent portable power units (Fig. 1) available, specifically designed for sewer cleaning, in which the engine, cable reel (with control clutch) and pulley frame are mounted on wheels and can be moved about as a trailer. At Champaign, Ill., the winch is mounted on the truck and is powered by the truck motor.

The sewer service crew of the Joint Meeting Sewer Commission of New Jersey is equipped with several unusual items which have proven highly useful.[3] A short-wave radio receiving set keeps the crew in contact with headquarters regardless of their location about the large area in which they must work; a portable platform derrick expedites heavy loading jobs and is used to transport the sewer cleaning winches; a portable, 1,500-watt generator supplies current for floodlights used in night work and for the portable air blower employed in ventilating sewers and manholes as a safety measure. Portable generators are also carried on some of the sewer maintenance trucks used at Los Angeles.[4]

The sewer maintenance departments of cities of moderate and small size are seldom equipped as completely as listed above, despite the fact that the best of equipment yields greatest economy. Commonly, the general purpose city truck is used to transport loose equipment or pull a small trailer. The truck is sometimes used to pull scoops, drags or brushes as a substitute for more suitable power machines. There is also an unfortunate tendency for small city crews to work without adequate safety equipment and fatal accidents in such crews are much too common. Phelps (San Diego) suggests that the cooperation of the local gas company be obtained when special testing equipment is required for occasional gas surveys.

Character of Sewer Stoppages

The most common obstructions in sewers, in the order of greatest incidence, are (1) roots, (2) accumulations of grease, (3) grit and (4) miscellaneous debris.

Roots generally enter at faulty joints. Growth usually occurs from a single leader root which continues developing inside the sewer until branches from the leader often fill the entire pipe. Phelps reports one root growth 30 feet in length (Fig. 4) removed from a sewer in San Diego. An unusual root removed in San Diego is shown in Fig. 5. Care in making joints, use of proper jointing materials and careful tamping of backfill during sewer construction are good insurance against root troubles later.

Copper, toxic to most plants, has been employed to control root growths. A copper ring, made for the purpose, is available for placing in the joint at the time the sewer is laid. Killing of root growths in sewers by copper sulfate is successfully practiced at San Diego, Cal., and Greenville, Tenn., and elsewhere, a handful of blue vitriol crystals being dropped into a manhole above the suspected root growth, while flow is taking place. Repeated applications may be necessary to kill the leader growth, which later break loose due to the water pressure behind it.

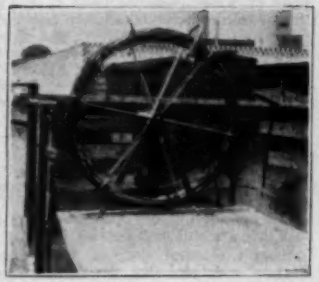

Fig. 2—Method of Using Flexible Sewer Rod Reel in Truck.

Superintendent Case of Merchantville, N. J., reports most root troubles caused by poplar and willow trees and these are removed where difficulty has been caused, to prevent recurrence.

Grease accumulations on the inside of the sewer and in the form of floating balls is a major problem at Atlantic City, N. J.,[5] and other places. Ordinarily discharged to the sewer with hot or warm water, the grease congeals as it cools and adheres to the walls of the sewer or develops into a ball with some small particle or object as a nucleus. These accumulations continue to build up until they materially reduce the capacity of the sewer.

Grit in the form of cinders, ashes, sand, mud, etc., which enters combined and storm sewers with surface water run-off and sanitary sewers with basement drainage, is often troublesome, particularly where sewers are on flat grades. At Rock Falls, Ill., and elsewhere, unpaved streets are the source of excessive grit deposits in sewers. Sewers laid through quicksand often shift due to the unstable foundation, opening at the joints and permitting the fine sand to enter. This condition is serious at East Aurora, N. Y., and, to a lesser extent, at Ocean City, N. J. Mud and sand originating at automobile wash racks is reported to be a cause of grit accumulation in sewers at Kahoka, Mo., and Cimarron, Kan.

Fig. 3—Power Driven Sewer "Drag" Mounted on Trailer at Ithaca, N. Y.

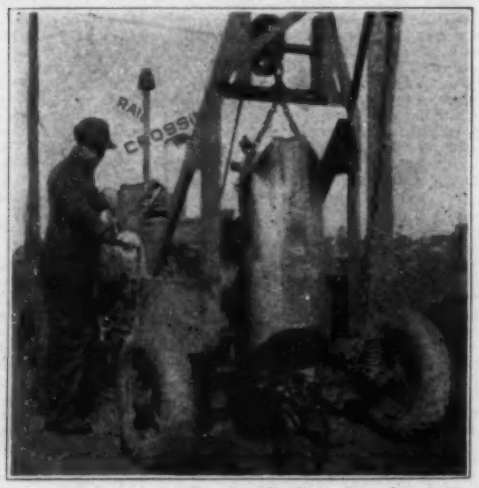

Fig. 1—Turbine Sewer Cleaning Machine at Bloomington, Ill.

The character of miscellaneous debris removed from sewers (combined and storm drains in particular) is almost unimaginable. Barrels, posts and a bed spring are on the list at Bloomington-Normal, Ill., and a washing machine was once removed from a large line at Springfield, Ill. Removal of some of these articles demands much ingenuity and patience on the part of sewer maintenance personnel.

Sewer Cleaning

Flushing.—Although not always positive, flushing of sewers is a convenient method of scouring out minor grit deposits and grease accumulations.

Surface water discharges during rains provide adequately for flushing storm and combined sewers, although supplementary flushing by fire hose is employed at Birmingham, Mich., Portland, Ore., and Sacramento, Cal., in conjunction with other cleaning operations, to clean lateral lines and to reduce odors at manholes in extended dry weather seasons. Routine flushing is a general practice in maintaining separate sanitary sewers but the frequencies reported vary from monthly to annually. At Orillia, Ontario, where the sanitary sewers have a minimum

slope of 5 per cent, Engineer L. G. McNeice indicates that annual flushing is practically the only maintenance required. In some cases, as at Ithaca, N. Y., and Kahoka, Mo., routine flushing is limited to critical lines on flat grades, which are flushed every two or three weeks. At Kahoka, some shallow lines are flushed after midnight by means of a time-clock actuated electric valve on the water service, giving a discharge of twenty minutes' duration.

Many old sewer systems were equipped with automatic flush tanks, located at the upper ends of laterals to assure scouring of deposits. Present practice is to design sewers with adequate slopes and the use of such devices is confined to lines in which flat grades are unavoidable. A number of contributors to this article indicate that old flush tanks have been abandoned; others that they are still used occasionally.

From a practical study of the hydraulics of sewer flushing, Watson[6] concludes that the *depth* of the flushing flow in the sewer is equally as important as the velocity. This accounts for the fact that flushing is most effective when the sewer is plugged at the lower manhole, the fire hose used to loosen grit deposits and grease accumulations and, after a head of sewage and water is built up, the plug is suddenly removed to release the flush. Kilpatrick (Rolla, Mo.) emphasizes the importance of blocking the sewer in connection with flushing operations. Sewer "bags," having a hose connection at one end and a nozzle in the other, are available for plugging the sewer and adding flushing water at the same time.

Satisfactory flushing by means of "water wagons" is accomplished at Los Angeles[7] and Lower Merion Township, Pa.[10] In the latter case, water is discharged at the upper manhole from a 625-gallon steel tank mounted on a truck and having a 6-in. drain valve. Discharge is so rapid that an 8-in. sewer is completely filled, giving an effective flush of 500 to 800 feet of sewer.

Hydrogen sulfide formation in sewage is accelerated by the presence of septic sludge deposits in sewers. Bowlus[11] reports that sulfides are definitely reduced after flushing, indicating that the practice is beneficial in reducing odors at manholes and treatment works as well as in reducing damage to sewers and concrete structures.

Removal of Roots.—For cutting and removing root growths in sewers up to 15 in. in diameter, flexible type rods and cutters appear to be very popular, because of the time saved, compactness of the equipment and small labor requirement. An augur-like cutter is used, which is rotated by twisting the rods as they are forced down the sewer. The equipment can be operated easily with two men if the power drive is used, or four men if the rods must be twisted manually. Another advantage of this equipment is that it can be fed into the sewer from ground level and does not require entry into manholes. Accumulations of roots removed at Cimarron, Kan., are shown in Fig. 6.

For removing roots from larger sewers, or particularly obstinate ones from small sewers, cutting drags are pulled through by cables and winches, either power or manually operated (Fig. 7). This procedure is positively effective, and in many cities is the only method used.

At Ocean City and Merchantville, N. J., every effort is made to prevent recurrence of root growths which are removed from sewers. Steelman at Ocean City reports that defective joints admitting roots are immediately located and repaired and some very troublesome lines have been relaid in iron pipe. Poplar and willow trees causing trouble at Merchantville are removed. Permanent control of roots in house service lines is the aim at Birmingham, Mich., where the city provides 6-in. cast iron pipe with leaded joints to the property line and requires not less than vitrified pipe with asphalt mastic joints inside the property. In case of root stoppage in old cement jointed vitrified pipe services (in the street), the city relays the service to the property line in cast iron pipe for a permit fee of $15.00.

Removal of Sand and Grit Deposits.—When flushing does not produce adequate results, sand buckets or scoops pulled through by the cable and winch outfit are universally depended upon for removing deposits of grit. This equipment (Fig. 1) is positive in effectiveness, regardless of the size of the accumulation.

Where the deposit is not too large, the "Turbine" cleaner which has a water powered, rotating cutter is effective. This device, dragged through the sewer by cable and winch, combines water jet flushing, cutting and dragging into one effective operation.

Rawn[7] describes an ingenious sewer "hoe" used by the Los Angeles County Sanitation Districts for removing grit accumulations from sewers over 30 in. in diameter with a minimum of labor. The device is propelled through the sewer by the pressure of sewage behind it and the invert and sides of the pipe are scoured as it moves. For sewers of 15 to 30 in. in diameter, a beach ball inflated to approximately the size of the sewer is used effectively in the same fashion as the "hoe."

Removal of Grease Accumulations.—Unless of industrial origin, sewer stoppages by grease are confined almost entirely to house services; however the capacity of larger sewers is often reduced due to the development of a grease lining in the pipe.

Flat sewer tapes with various kinds of cleaning tools are used for removing grease obstructions from house connections at Ocean City, N. J. Large sewers give no trouble here. At Atlantic City, N. J.,[4] the most useful device for opening house

Fig. 4—A Few Roots from a San Diego Sewer.

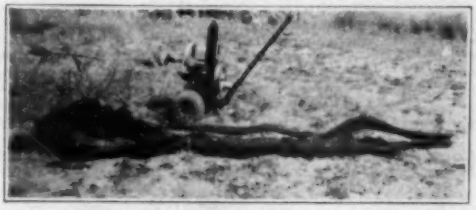

Fig. 5—Not a Sea Monster—A Root Removed in San Diego by Power Driven Flexible-rod and Cutter.

Fig. 6—Root Removed by Flexible Sewer Rod Equipment at Cimarron, Kas.—City Engr. Cruisinberry at Right.

connections has been found to be a 50-ft. length of quarter-inch steel wire. The end started into the sewer has a 6-in. bend which is rotated by cranking the other end as the wire is fed, thus gouging out the stoppage.

Grease accumulations in larger sewers are loosened to some extent by flushing, root-cutting and other maintenance operations. Sewer brushes, dragged through by the ever useful winch and cable equipment, are most positive, however, and many well-trained crews always use a brush drag to finish up a line that has been dragged with other tools.

Other Cleaning Devices.—It will be noted that certain types of equipment are best suited to specific cleaning problems, yet it may often be necessary to use practically all of the equipment carried for cleaning a single line. For instance, the flexible rod and root cutter and/or detachable wooden rods may be used to partially open a stoppage to permit a cable to be threaded through for use in dragging, and several types of drags may be employed. Unusual situations will often demand considerable thought and ingenuity on the part of the maintenance crew even though they are well equipped for ordinary problems.

The sewer "hoe" and beach ball cleaners described above are examples of such ingenuity. The Los Angeles County Sanitation Districts, where these labor-saving implements were devised, makes root cutting drags for 12 to 36-in. sewers from steel pipe[7]; sewer brushes at Ithaca, N. Y., are made from old street-sweeper brooms; a knot of old chain has been found to constitute a serviceable root cutter and drag at Portland, Ore.; a 15-in. root cutter was made to service an 18-in. sewer at Urbana-Champaign, Ill., by wrapping the periphery with barbed wire, further illustrating actual practice in meeting local problems.

Ground Water Infiltration

Although most ground water infiltration results from faulty sewer construction (poor joints or failure to use proper pipe through critical water-bearing soil formations), good maintenance and operation practices can reduce this problem. In referring to infiltration, nearly all of the contributors to this article mentioned the relatively new asphalt mastic jointing compounds as a curative measure, either in explaining why there was no serious infiltration problem or describing how it is being minimized in new extensions or old sewer repairs.

Where there is ample sewer capacity, gravity flow and no sewage treatment works, there is an inclination to disregard infiltration to some extent. Usually the allowance for infiltration in the design of separate sanitary sewers is only nominal but such leakage often proves to be of serious consequence, as at Ithaca, N. Y., where it amounts to 100 to 400 per cent of the dry weather sewage flow due to broken pipe and poor joints. Superintendent Carpenter indicates that correction can be accomplished only by replacement of the defective lines by cast iron or other suitable pipe.

Where sewage must be pumped, it has been found economical to locate and actually replace those lines admitting large amounts of ground water. This has been done at McHenry and Fox River Grove, Ill., Rolla, Mo., and elsewhere.

Steelman (Ocean City, N. J.) and Bridges (Kahoka, Mo.) point out the necessity of careful control and inspection of house connections to minimize infiltration. The sharp increase in flow in sanitary sewers during rains is usually caused by illicit downspout connections which are most difficult to control since many of them are changed after the installation inspection is made. Constant vigilance, public education and rigid enforcement of ordinance provisions are the only possible means of minimizing this source of extraneous water. Kahoka, Mo., and Birmingham, Mich., sewer users are required to comply with strict specifications for workmanship and materials in constructing house sewers.

Maintenance of Appurtenant Sewerage Structures

Aside from ordinary inspection and replacement of broken manhole covers, it is important that manholes in unimproved or semi-permanent streets be maintained at the proper elevation. Considerable damage to such streets is done when an attempt is made to find a manhole which has been covered. Rattling manhole lids often create a nuisance and correction has been accomplished by: application of tar or asphalt around the entire rim or at three or four points[8]; gaskets of rubber, jute or canvas; machining of the lid and casting; use of mechanical locking lids or low center of gravity types. Anderson,[3] after trying several methods, now uses a tape packing made for the purpose which is placed around the entire periphery after thorough cleaning of the casting.

Other appurtenances common to separate sanitary sewers are inverted siphons, creek crossings and flush tanks. Inverted siphons must be inspected frequently as they are readily clogged by accumulations at the inlet or grit deposits in the siphon pipes. Two siphons on intercepting sewers at Champaign-Urbana, Ill., are inspected at least weekly and cleared of inlet accumulations. Three siphons at Ithaca, N. Y., are flushed out every four months. Creek crossing structures are generally checked following wet seasons to ascertain erosion damage, replace protecting rip-rap or make repairs. Flush tanks maintained in regular service are inspected monthly and afforded cleaning and adjustment.

Frequent cleaning of catch basins on storm or combined sewer systems is justified by the protection they provide against grit deposits in the sewers. Practice appears to be to clean these at least annually where paved streets are drained and more often when streets do not have a permanent surface. Street inlets are inspected and cleared after every rain at Rock Falls, Ill., to assure good street drainage. Storm water overflows are inspected and given necessary attention at least once monthly at Birmingham, Mich., and Bloomington, Ill., with more frequent attention being accorded in wet seasons. Sewage flow regulators and adjustable overflows in combined systems are best attended during high flows so that they may be adjusted to actual operating conditions.

Regulation of Use of Sewers

Probably no other public utility is misused to so great a degree as is the sewer system, yet there is always readiness on the part of the public to criticize faulty operation. This condition is no doubt largely due to the lack of public education and to the failure of city officials to adopt and *enforce* proper ordinances controlling the usage of sewers. Such an ordinance does no good if merely filed among the dusty archives of the municipality—it must set forth proper practices, contain adequate penalties and be enforced without hesitancy when courteous requests for cooperation are ignored.

Anderson[3] points out that the best way to obtain public cooperation is to definitely allocate responsibility for house sewer connections to the property owner, requiring him to pay for any maintenance work necessary on these lines. Many eastern cities have established a policy of accepting responsibility for all sewers outside the curb, which practice appears to have several advantages. The Atlantic City Sewerage Co.[9] requires a trap on each house service at the curb and responsibility in each case is determined by examination of the trap. The company services all sewers outside the curb and local plumbers perform at the property owner's expense any work needed from the curb to the house.

Among the more important items warranting inclusion in the sewer ordinance are:

1. Control over location of certain trees (poplar and willow) which might cause root stoppages, including authority to remove such trees found to cause trouble.
2. Prohibition of downspout and similar surface water connections from separate sanitary sewers.
3. Provision for detailed inspection by competent personnel of all house service installations. Also rigid specifications covering workmanship and material in house services.
4. Requirement of suitable preliminary treatment facilities in commercial and industrial concerns to prevent damage to sewers. Wastes commonly controlled for this purpose are: (a) Greasy wastes from restaurants, packing plants, etc.; (b) oil and dirt from automobile filling stations and wash racks; (c) Inflammable and explosive wastes from cleaning establishments; (d) wastes containing excessive solids, such as spent grain from breweries, paunch manure from packing plants, ashes, garbage, etc.; (e) corrosive wastes, as those from metal galvanizing and pickling plants.
5. Requirement of suitable preliminary treatment facilities in industries to prevent interference with sewage treatment plant operation.
6. Provision for stern penalties for malicious damage by vandals.

A combination grit and oil trap recommended by the South Dakota Board of Health[4] for use on sewers from garages, filling stations and automobile wash racks is shown in Fig. 7. The oil problem is successfully met at Baltimore[3] by requiring by ordinance that such waste be stored on the premises until collected periodically for disposal under direct control of municipal authorities. The provision of a convenient means of disposal of the oil eliminates need for policing garages and similar establishments.

After a bad fire caused by waste oil and gasoline dumped to sewers at Aurora, Ill., Superintendent W. A. Sperry acted to prevent a recurrence by means of newspaper publicity and direct contact with industrial sources of volatile wastes. The latter was accomplished by a plant-to-plant canvass of 245 industrial and commercial establishments, during which a verbal notice

was given a responsible representative of each concern, a poster epitomizing the sewer ordinance was left and a signed acknowledgement of each visit was obtained. The survey cost $100 and appears to be good insurance against future damage, although it must probably be repeated after several years.

Sewer Ventilation

Ventilation in sewers is necessary to dilute and purge the system of gases which are inflammable, explosive, asphyxiant and toxic. In warm climates where hydrogen sulfide is often a problem, ventilation is also beneficial in controlling disintegration of concrete sewers and structures because (a) the concentration of H_2S in the atmosphere and (b) collection of moisture on exposed surfaces, are reduced.

The degree of effective ventilation in a sewer is usually dependent upon the amount of vent openings and the movement of air across the openings. Thus, it appears that natural ventilation is at a minimum on still days.

Forced ventilation has been found justified in large outfall sewers at Los Angeles[9] and several ventilation stations are in development. Ordinary ventilation practice is probably represented by the procedure at Lower Merion Twp., Pa.[10] "Ventilating covers" having eight 1-in. openings are placed at the upper ends of all lines and approximately at each third manhole, with consideration being given to surface water drainage and proximity to points at which odor might be troublesome, when selecting locations. Buckets are hung beneath ventilating covers to catch debris which might pass through the openings.

To guard against fires and explosions and to eliminate conditions dangerous to sewer maintenance personnel, the city of Los Angeles[9] has a gas survey crew which systematically checks the entire system, making observations at about 60,000 manholes per year. Results of various gas detector tests are recorded and used as basis for correction of dangerous conditions. When the presence of illuminating gas is suspected, the utility company is immediately notified so that any gas main leak may be repaired.

Design and Construction Items Facilitating Maintenance

Good design and careful construction of a sewer system will reduce maintenance to a minimum and expedite such work as is necessary. There has been sufficient experience at this time to substantiate present methods of ascertaining sewer sizes and grades, yet there is often a tendency to violate the limitations of good practice, particularly with respect to grades. Every effort to avoid capital and operating costs of pumping stations is certainly justified, but consideration must also be given the less satisfactory service and everlasting maintenance expense which accompany the installation of sewers on flat grades. Where moderate reductions in slope are logical, provision of adequate, suitable flushing facilities constitutes good practice.

The prevalence of difficulties from roots and ground water infiltration is ample proof that too much care cannot be taken in specifying and installing permanently tight joints. This fact, of course, is generally appreciated and modern jointing methods and materials are already demonstrating their superiority. Careful specification and performance of back-filling is also important in preventing crushing of pipe and movement which results in opening of joints. The use of especially suited pipe and construction methods in sections where foundation conditions are bad or where excessive ground water is present, has been proven to be good economy, even though more expensive in first cost.

Other design and construction details suggested by maintenance personnel as being of importance to their functions are the following:

1. Design of junction chambers so that back-water areas of low velocity, causing deposition of grit, are avoided.
2. Design of storm water overflows so that they are not accessible by vandals.
3. Catch basins of ample size at storm water inlets draining unpaved streets.
4. Complete consideration of local conditions when selecting the type of pipe used for sanitary and industrial sewers.
5. Spacing of manholes not more than 350 feet apart.
6. Lateral sanitary sewers of not less than 8 inches diameter.
7. Smooth flow without splashing or turbulence at manholes or appurtenant structures. (Important where hydrogen sulfide might be a problem.)
8. Diversion and regulator devices of simple design and capable of convenient adjustment.

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Fig. 7—Manually Operated Sewer "Drag" in Ithaca, N. Y.

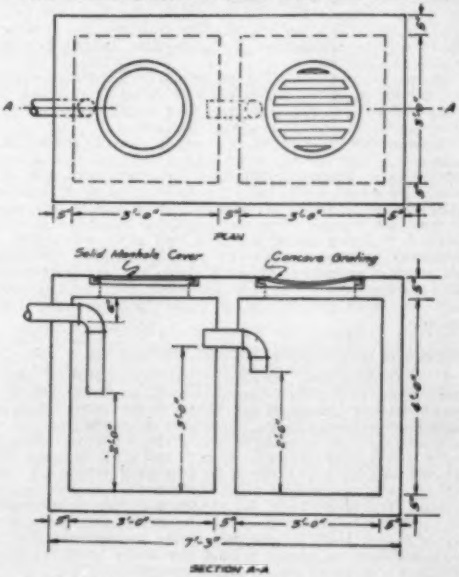

Fig. 8—Combination Oil Trap and Grit Basin for Garages and Filling Stations. Recommended by South Dakota State Board of Health.

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Specifically designed and engineered for comminution and grit removal

COMMINUTOR

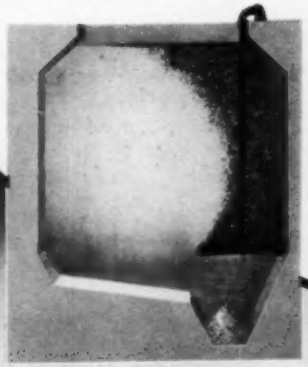
The only equipment that unfailingly cuts coarse sewage matter into small settleable solids without removal from the channel. Over 2500 installed since 1934.

1. Precision Engineered
2. Ruggedly Constructed
3. Properly Designed Cutters and Shear Bars
4. Controlled Feed and Flow

AER-DEGRITTER

The only method of removing organic-free grit and sand from sewage without cloggable mechanical equipment.

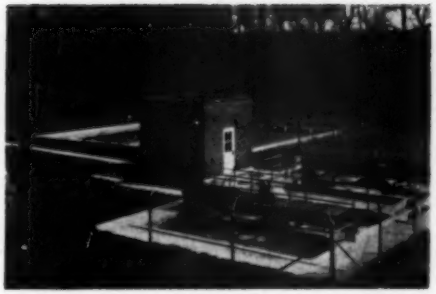
1. Maximum Removal
2. Clean Grit
3. No Mechanisms to Clog
4. Air Controlled Velocities
5. Low Cost
6. Simple Structure



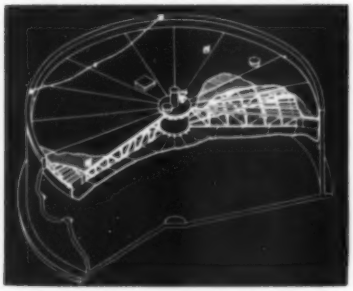
CHICAGO SEWAGE EQUIPMENT

CHICAGO 'PAKAGE' PLANT

Specifically designed for small communities, institutions and industrial plants, the Chicago 'Pakage' Plant combines in one installation all functional equipment found in a big city activated sludge sewage treatment plant. Low initial and operating costs, with minimum supervision required. Operators, without previous experience, successfully run plants and perform other municipal duties. Over 200 units installed since 1934.



CHICAGO-WIGGINS PONTOON COVERS AND GAS HOLDERS



Now the Chicago-Wiggins Pontoon Cover, designed specifically for sewage digesters, combines the experience of Chicago Sewage Equipment Engineers and John H. Wiggins. Over 4000 Wiggins Floating Covers have been installed in the last 25 years. Chicago-Wiggins Pontoon Covers, Gas Holders and Lo-Dek Covers incorporate the latest techniques in design and construction, providing greater strength with less weight and with ample safety factor. Chicago-Wiggins Covers cannot tip.

Specifically designed and engineered for sewage digesters

CHICAGO-WIGGINS LO-DEK COVERS • TRU TEST SEWAGE SAMPLERS

Specifically designed and engineered for activated sludge sewage treatment plants

CHICAGO SWING DIFFUSERS AND PRECISION DIFFUSER TUBES

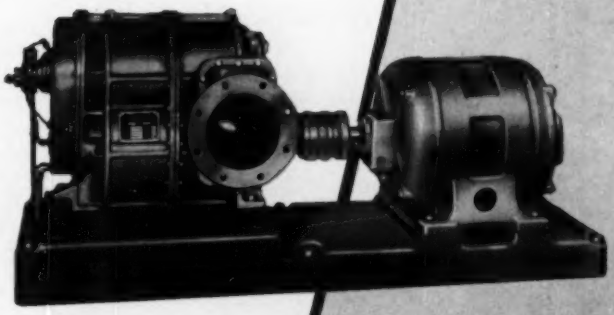
Continuous operation of an aeration battery is possible only with Chicago Swing Diffusers. No stand-by tanks are necessary. Chicago Precision Diffuser Tubes permit the most economical operation of an aeration battery. The Tubes are easily cleaned at a cost of only 10c. Swing Diffusers have been installed in over 200 plants since 1937.

1. Low first cost—no standby tanks.
2. Continuous operation at maximum efficiency.
3. Economical operation—less power consumed —less labor.
4. Tubes easily and economically cleaned.

CHICAGO STANDARDAIRE BLOWER

The Chicago Standardaire Blower is the most efficient, quiet, compact blower designed for sewage treatment. Air is delivered in a steady stream. No backsurge to cause pounding and clatter. Because of this greater efficiency, lower applied horsepowers are needed per C.F.M. of air. Precision engineering and select materials insure long life under continuous operation.

20 to 15,000 C.F.M. Up to 20 psi.



CHICAGO PUMP COMPANY
SEWAGE EQUIPMENT DIVISION

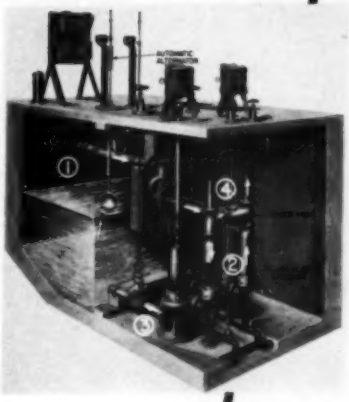
HEAT EXCHANGERS · CHICAGO NON-CLOG PUMPS · WATER SEAL UNITS

CHICAGO SEWAGE EQUIPMENT

Specifically designed and engineered for pumping sewage and sludge

FLUSH-KLEEN EJECTORS

The Chicago Flush-Kleen Sewage Ejector is the *only* positively clog proof sewage pump. The impellers handle only strained sewage. No solids can clog impeller or cause excessive wear on shaft and bearings. No manual attention required except for periodic lubrication.



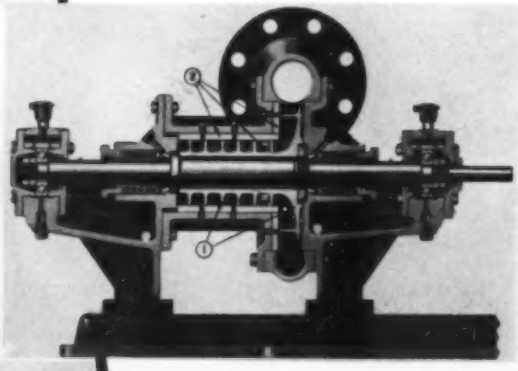
Filling Wet Well

1. Sewage flows through inlet pipe.
2. Coarse matter is retained on strainer.
3. Strained sewage flows through idle pump to wet well.

Pumping

3. Strained sewage is pumped from wet well.
2. Coarse matter is backwashed on strainer.
4. Special check valve closes. Sewage and coarse matter are pumped to sewers.

SCRU-PELLER SLUDGE PUMPS



The Scru-Peller Pump is specifically designed to handle sludge. Coarse, stringy material is cut and cannot wrap or bind the impellers.

1. Screw and Impeller are keyed to the shaft and firmly held against the shaft shoulder by the shaft nut. The screw has two flights; the impeller two blades. Each screw flight in the conveyor is connected with its own impeller.
2. Cutting edges consist of four stellited cutting bars and a shear ring in the pump casing. The stellited screw edges and the edges of impeller blades act against cutting bars and shear ring, completely chopping all coarse solids into small pieces that cannot clog or slow the pump.

CHICAGO PUMP COMPANY

SEWAGE EQUIPMENT DIVISION

2300 WOLFRAM STREET CHICAGO 18, ILLINOIS

CUBIC FEET, GALLONS, POUNDS, AND TONS OF WATER IN RECTANGULAR TANKS*

THIS chart will be found useful for rectangular tank determinations. The dimensions of the tank, all in inches, are given in columns A, C, and D. Then, as will be noted, you can find the number of cubic feet in column E, the gallons in column F, the pounds of water in column G, and the tons of water in column H. As a typical example, let us say that the width of a given tank is 10 inches, the depth 5 inches, and the length 20 inches. How many pounds of water will the tank hold?

How to Use the Chart

Find the 10 in column A and run a straight line over to the 5 in column C and locate the intersection with column B. Then from that point of intersection run over to the 20 in column D, and note the intersection with column C. It will be observed now that column C and J are exactly alike so that perfectly horizontal lines can be drawn between those two columns. In this instance the intersection in column C happens to be through the 10, so simply run a straight line through the 10 in column C and the 10 in column J, as shown by the dotted line, and you have a perfectly horizontal line which gives all of the answers as follows:

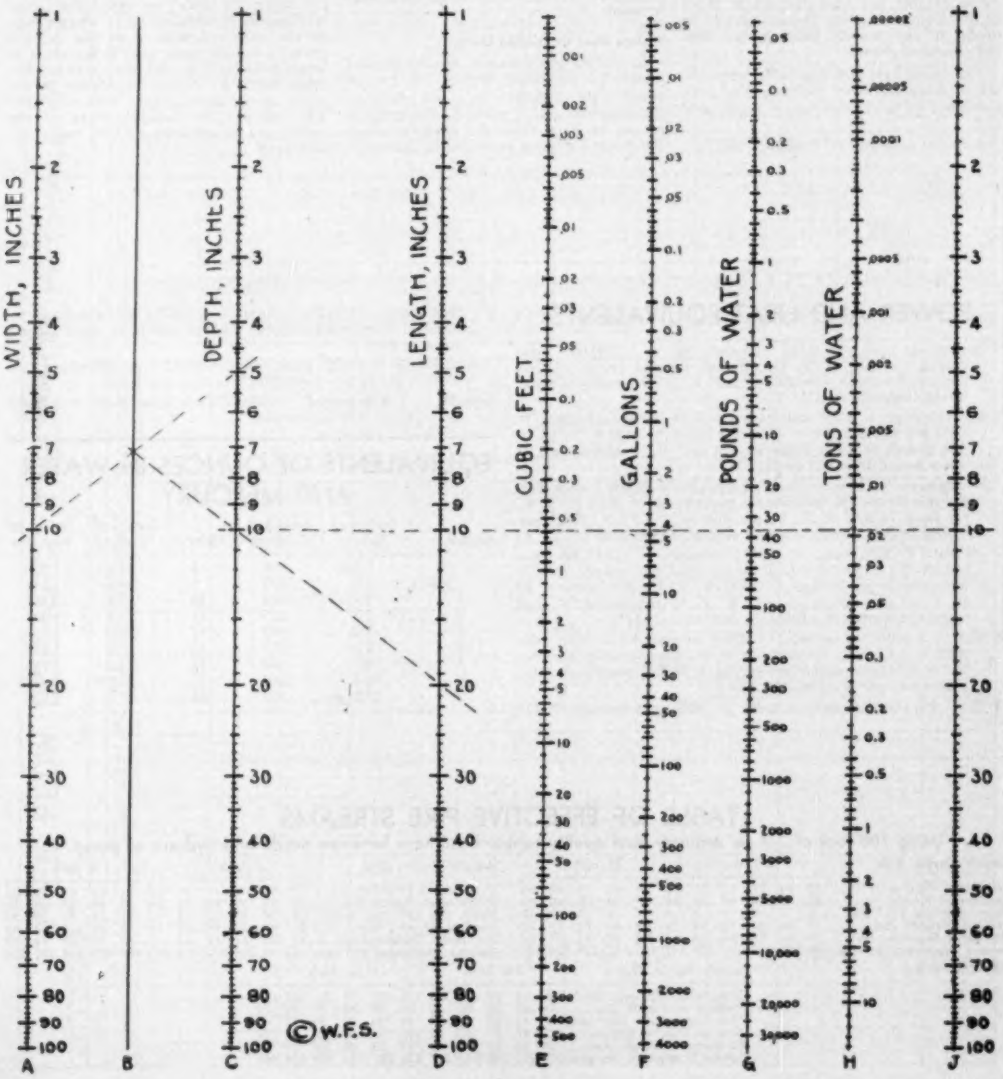
Column E shows that the tank has a volume of nearly 0.6 cu. ft.

Column F shows that the number of gallons is about 4.3.

Column G shows that if the tank contains water the weight will be about 37 pounds.

Column H shows that the number of tons of water is approximately .0185.

*Contributed by W. F. Schaphorst, M.E., Newark, N. J.



FREE-FLOW DISCHARGE TABLE FOR PARSHALL MEASURING FLUMES

By N. W. NESTER and G. C. HANES
Captain San. Engr.
*Corps of Engineers, U. S. Army**

THE accompanying table has been prepared to bring together in one place, significant data for use in the determination of free-flow discharge for Parshall measuring flumes of 5 different sizes. This particular chart has found effective use in the 9th Service Command Area where many Parshall flumes are installed.

It has proved helpful to field engineers of the Headquarters office as well as to plant operators, and while the range of throat widths has been limited to those in this Command area, the data should be useful to any sewage plant having that size Parshall flume.

The basic data for this table were obtained from Farmers' Bulletin No. 1683, published by the U. S. Dept. of Agric. and titled "Measuring Water in Irrigation Channels" by R. L. Parshall, Sr. Irrigation Engr., Div. of Irrigation, Soil Conservation Service.

The table has proved useful as a check on indicating and recording flow meters that have been installed on Parshall flumes. Frequently, discrepancies may be found, as for example, a meter installed on a flume with a throat width larger or smaller than that for which it was designed; or the wrong meter chart may be used.

Testing Float Controlled Meters

In testing the common float-controlled meter, the following method has proved simple but satisfactory. The float is disconnected and a point on the cable is moved by hand from the position where the meter indicates zero flow to the maximum for which the flume was designed, in increments of one inch or one-tenth foot. The point is then moved down the scale so that the meter again indicates zero. The corresponding readings on the meter for each point on the scale are noted. This procedure is repeated several times in order to obtain an average.

The results of these observations are plotted on a graph containing a curve for the throat width (made from data in the accompanying table) on which the meter mechanism is installed. Any discrepancy of the observed data from the correct curve is readily apparent. If the error is large, it is well to plot the curve of another flume of larger or smaller throat width on the same graph. This will usually indicate the design curves of the meter and corrections may be made accordingly.

*9th Service Command, Ft. Douglas, Utah.

POWER AND HEAT EQUIVALENTS

1 horsepower-hour = 0.746 kilowatt-hour = 1,980,000 foot-pounds = 2550 B. T. U. (British thermal units) = 2.64 pounds of water evaporated at 212° F. = 17 pounds of water raised from 62° to 212° F.

1 kilowatt-hour = 1000 watt-hours = 1.34 horsepower-hour = 2,653,200 foot-pounds = 3,600,000 joules = 3420 B. T. U. = 3.54 pounds of water evaporated at 212° F. = 22.8 pounds of water raised from 62° to 212° F.

1 horsepower = 746 watts = 0.746 kilowatt = 33,000 foot-pounds per minute = 550 foot-pounds per second = 2550 B. T. U. per hour = 42.5 B. T. U. per minute = 0.71 B. T. U. per second = 2.64 pounds of water evaporated per hour at 212° F.

1 kilowatt = 1000 watts = 1.34 horsepower = 2,653,200 foot-pounds per hour = 44,220 foot-pounds per minute = 737 foot-pounds per second = 3420 B. T. U. per hour = 57 B. T. U. per minute = 0.95 B. T. U. per second = 3.54 pounds of water evaporated per hour at 212° F.

1 watt = 1 joule per second = 0.00134 horsepower = 0.001 kilowatt = 3.42 B. T. U. per hour = 44.22 foot-pounds per minute = 0.74 foot-pounds per second = 0.0035 pounds of water evaporated per hour at 212° F.

1 B. T. U. (British thermal unit) = 1052 watt-seconds = 778 foot-pounds = 0.252 calorie = 0.000292 kilowatt-hour = 0.000391 horsepower-hour = 0.00104 pounds of water evaporated at 212° F.

1 foot-pound = 1.36 joule = 0.000000377 kilowatt-hour = 0.00129 B. T. U. = 0.0000005 horsepower-hour.

1 joule = 1 watt-second = .000000278 kilowatt-hour = 0.00095 B. T. U. = 0.74 foot-pound.

EQUIVALENTS OF OUNCES IN WATER AND MERCURY

Ounces	Inches of Water	Inches of Mercury	Ounces	Inches of Water	Inches of Mercury
.3	.521	.038	8	13.9	1.020
.576	1.0	.073	9	15.6	1.148
1	1.7	.128	10	17.4	1.275
2	3.5	.255	11	19.1	1.403
3	5.2	.383	12	20.8	1.530
4	6.9	.510	13	22.6	1.658
5	8.7	.638	14	24.3	1.785
6	10.4	.765	15	26.3	1.913
7	12.2	.893	16	27.8	2.036

TABLE OF EFFECTIVE FIRE STREAMS

Using 100 feet of 2½-in. ordinary best quality rubber-lined hose between nozzle and hydrant or pump.

Smooth Nozzle, Size	¾ Inch						⅞ inch					
Pressure at Hydrants, lbs.	32	43	54	65	75	86	34	46	57	69	80	
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70	
Press. lost 100' 2½" hose	2	3	4	5	5	6	4	6	7	9	10	
Vertical Height, feet	48	60	67	72	76	79	49	62	71	77	81	
Horizontal Distance, feet	37	44	50	54	58	62	42	49	55	61	66	
Gallons Discharged per min.	90	100	116	127	137	147	123	142	159	174	188	

Smooth Nozzle, Size	1 Inch						1⅛ Inch					
Pressure at Hydrant, lbs.	37	50	62	73	85	97	41	54	67	80	93	
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70	
Press. lost 100' 2½" hose	7	10	12	13	15	17	11	14	17	20	23	
Vertical Height, feet	51	64	73	79	85	89	52	65	75	83	88	
Horizontal Distance, feet	47	55	61	67	72	76	50	59	66	72	77	
Gallons Discharged per min.	161	186	208	228	246	263	206	238	266	291	314	

Smooth Nozzle, Size	1¼ Inch						1⅜ Inch					
Pressure at Hydrant, lbs.	46	60	75	90	104	119	52	69	86	102	119	
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70	
Press. lost per 100' 2½" hose	16	20	25	30	34	39	22	29	36	42	49	
Vertical Height, feet	53	67	77	85	91	95	55	69	79	87	92	
Horizontal Distance, feet	54	63	70	76	81	85	56	66	73	79	84	
Gallons Discharged per min.	253	293	326	357	386	413	307	354	396	434	469	

FREE FLOW DISCHARGE TABLE FOR PARSHALL MEASURING FLUME

U.S.G.S. — U.S.W.B.

SEC-FT. X .646317 = M.G.D. — M.G.D. X 1.547823 = SEC-FT. — SEC-FT. X 448.831 = G.P.M. — G.P.M. X .0022828 = SEC-FT.

THROAT WIDTH

HEAD		6"			9"			12"			18"			24"		
FT.	IN.	SEC-FT	G.P.M.	M.G.D.	SEC.FT	G.P.M.	M.G.D.	SEC.FT	G.P.M.	M.G.D.	SEC-FT	G.P.M.	M.G.D	SEC.FT	G.P.M.	M.G.D.
0.10	1 1/16	0.05	22.4	0.032	0.08	40.4	.0500									
0.11	1 1/16	0.06	26.9	0.039	0.10	44.9	.0650									
0.12	1 1/16	0.07	31.4	0.045	0.12	53.8	.0775									
0.13	1 1/16	0.08	35.9	0.052	0.14	62.8	.0905									
0.14	1 1/16	0.09	40.4	0.058	0.15	67.3	.0970									
0.15	1 1/16	0.10	44.9	0.065	0.17	76.3	.1100									
0.16	1 1/16	0.11	49.4	0.071	0.19	85.2	.1230									
0.17	2 1/16	0.12	53.8	0.077	0.20	89.8	.1290									
0.18	2 1/16	0.14	62.8	0.090	0.22	98.7	.1420									
0.19	2 1/16	0.15	67.3	0.097	0.24	107.7	.1550									
0.20	2 1/16	0.16	71.8	0.103	0.26	116.9	.1680	0.35	157.1	0.226	0.51	229.0	0.330	0.66	296.3	0.426
0.21	2 1/16	0.18	80.7	0.116	0.28	125.7	.1810	0.37	166.1	0.239	0.55	247.0	0.355	0.71	318.7	0.458
0.22	2 1/16	0.19	85.2	0.123	0.30	134.6	.1940	0.40	179.5	0.259	0.59	265.0	0.381	0.77	345.6	0.498
0.23	2 1/16	0.20	89.8	0.129	0.32	143.6	.2070	0.43	193.0	0.278	0.63	283.0	0.407	0.82	368.0	0.530
0.24	2 1/16	0.22	98.7	0.142	0.35	157.1	.2260	0.46	206.5	0.297	0.67	301.0	0.433	0.88	395.0	0.569
0.25	3	0.23	103.3	0.149	0.37	166.1	.2390	0.49	219.9	0.316	0.71	318.7	0.458	0.93	417.5	0.601
0.26	3 1/16	0.25	112.2	0.162	0.39	175.1	.2520	0.51	229.0	0.330	0.76	341.1	0.491	0.99	444.3	0.640
0.27	3 1/16	0.26	116.9	0.168	0.41	184.0	.2650	0.54	242.3	0.349	0.80	359.0	0.517	1.05	471.3	0.679
0.28	3 1/16	0.28	125.7	0.181	0.44	197.5	.2840	0.58	260.3	0.374	0.85	381.5	0.549	1.11	498.2	0.717
0.29	3 1/16	0.29	130.2	0.187	0.46	206.5	.2970	0.61	274.0	0.394	0.90	404.0	0.582	1.18	530.0	0.763
0.30	3 1/16	0.31	139.2	0.203	0.49	219.9	.3160	0.64	287.3	0.414	0.94	422.0	0.607	1.24	556.6	0.801
0.31	3 1/16	0.32	143.6	0.207	0.51	229.0	.3300	0.68	305.2	0.439	0.99	444.3	0.640	1.30	583.4	0.840
0.32	3 1/16	0.34	152.6	0.220	0.54	242.3	.3490	0.71	318.7	0.458	1.04	466.8	0.672	1.37	615.0	0.886
0.33	3 1/16	0.36	161.5	0.233	0.56	251.3	.3620	0.74	332.0	0.478	1.09	489.0	0.704	1.44	646.0	0.930
0.34	4 1/16	0.38	170.5	0.246	0.59	265.0	.3810	0.77	345.6	0.498	1.14	512.0	0.737	1.50	673.2	0.969
0.35	4 1/16	0.39	175.1	0.252	0.62	278.0	.4010	0.80	358.0	0.517	1.19	534.0	0.769	1.57	705.0	1.015
0.36	4 1/16	0.41	184.0	0.265	0.64	287.3	.4140	0.84	377.0	0.543	1.25	561.0	0.808	1.64	736.0	1.060
0.37	4 1/16	0.43	193.0	0.278	0.67	301.0	.4330	0.88	395.0	0.569	1.30	583.4	0.840	1.72	772.0	1.111
0.38	4 1/16	0.45	201.9	0.291	0.70	314.0	.4520	0.92	412.9	0.594	1.36	610.0	0.878	1.79	803.4	1.156
0.39	4 1/16	0.47	210.9	0.304	0.73	327.6	.4720	0.95	426.0	0.614	1.41	633.0	0.911	1.86	835.0	1.202
0.40	4 1/16	0.48	215.5	0.310	0.76	341.1	.4912	0.99	444.3	0.640	1.47	659.0	0.950	1.93	866.0	1.247
0.41	4 1/16	0.50	224.4	0.323	0.78	350.0	.5040	1.03	462.0	0.666	1.53	686.0	0.989	2.01	902.0	1.299
0.42	5 1/16	0.52	233.3	0.336	0.81	363.5	.5240	1.07	480.0	0.692	1.58	709.0	1.021	2.09	938.0	1.350
0.43	5 1/16	0.54	242.3	0.349	0.84	377.0	.5430	1.11	498.1	0.717	1.64	736.0	1.060	2.16	969.0	1.396
0.44	5 1/16	0.56	251.3	0.362	0.87	390.4	.5620	1.15	516.0	0.743	1.70	763.0	1.098	2.24	1005	1.447
0.45	5 1/16	0.58	260.3	0.375	0.90	404.0	.5820	1.19	534.0	0.769	1.76	790.0	1.137	2.32	1041	1.499
0.46	5 1/16	0.61	274.0	0.394	0.94	422.0	.6075	1.23	552.0	0.795	1.82	816.0	1.176	2.40	1077	1.551
0.47	5 1/16	0.63	283.0	0.407	0.97	435.0	.6270	1.27	570.0	0.821	1.88	843.0	1.215	2.48	1113	1.602
0.48	5 1/16	0.65	292.0	0.420	1.00	448.8	.6460	1.31	588.0	0.847	1.94	870.0	1.254	2.57	1153	1.661
0.49	5 1/16	0.67	301.0	0.433	1.03	462.0	.6660	1.35	606.0	0.872	2.00	896.0	1.293	2.65	1189	1.712
0.50	6	0.69	310.0	0.446	1.06	475.7	.6850	1.39	624.0	0.898	2.06	925.0	1.331	2.73	1225	1.764
0.51	6 1/16	0.71	318.7	0.459	1.10	493.7	.7109	1.44	646.0	0.930	2.13	956.0	1.376	2.82	1266	1.822
0.52	6 1/16	0.73	327.6	0.472	1.13	507.0	.7300	1.48	664.0	0.956	2.19	983.0	1.415	2.90	1301	1.875
0.53	6 1/16	0.76	341.1	0.491	1.16	521.0	.7500	1.52	682.0	0.982	2.25	1010	1.454	2.99	1342	1.932
0.54	6 1/16	0.78	350.0	0.504	1.20	538.0	.7760	1.57	705.0	1.015	2.32	1041	1.499	3.08	1382	1.990
0.55	6 1/16	0.80	359.0	0.517	1.23	552.0	.7950	1.62	727.0	1.047	2.39	1073	1.545	3.17	1422	2.049
0.56	6 1/16	0.82	368.0	0.530	1.26	565.5	.8140	1.66	745.0	1.073	2.45	1099	1.583	3.26	1463	2.107
0.57	6 1/16	0.85	381.5	0.549	1.30	583.4	.8400	1.70	763.0	1.098	2.52	1131	1.628	3.35	1504	2.165
0.58	6 1/16	0.87	390.4	0.562	1.33	597.0	.8600	1.75	786.0	1.131	2.59	1163	1.674	3.44	1544	2.224
0.59	7 1/16	0.89	399.5	0.575	1.37	615.0	.8860	1.80	808.0	1.163	2.66	1194	1.719	3.53	1585	2.282
0.60	7 1/16	0.92	412.9	0.595	1.40	628.0	.9050	1.84	826.0	1.189	2.73	1225	1.764	3.62	1625	2.340
0.61	7 1/16	0.94	422.0	0.608	1.44	646.0	.9300	1.88	843.0	1.215	2.80	1257	1.809	3.72	1670	2.404
0.62	7 1/16	0.97	435.0	0.627	1.48	664.0	.9560	1.93	866.0	1.247	2.87	1290	1.855	3.81	1710	2.463
0.63	7 1/16	0.99	444.3	0.640	1.51	678.0	.9760	1.98	889.0	1.280	2.95	1324	1.907	3.91	1755	2.527
0.64	7 1/16	1.02	457.8	0.659	1.55	696.0	1.002	2.03	911.0	1.312	3.02	1355	1.952	4.01	1800	2.592
0.65	7 1/16	1.04	466.8	0.672	1.59	714.0	1.028	2.08	934.0	1.345	3.09	1387	1.997	4.11	1845	2.656
0.66	7 1/16	1.07	480.0	0.692	1.63	732.0	1.054	2.13	956.0	1.376	3.17	1422	2.049	4.20	1885	2.714
0.67	8 1/16	1.10	493.7	0.711	1.68	745.0	1.073	2.18	978.0	1.409	3.24	1454	2.094	4.30	1930	2.780
0.68	8 1/16	1.12	503.0	0.724	1.70	763.0	1.098	2.23	1001	1.441	3.31	1486	2.140	4.40	1975	2.844
0.69	8 1/16	1.15	516.0	0.743	1.74	781.0	1.125	2.28	1024	1.474	3.39	1522	2.191	4.50	2020	2.908
0.70	8 1/16	1.17	525.1	0.756	1.78	799.0	1.151	2.33	1046	1.506	3.46	1553	2.236	4.60	2069	2.973

HEAD		6"			9"			12"			18"			24"		
FT.	IN.	SEC.FT.	G.P.M.	M.G.D.	SEC.FT	G.P.M.	M.G.D	SEC.FT	G.P.M.	M.G.D	SEC-FT	G.P.M.	M.G.D.	SEC.FT	G.P.M.	M.G.D.
0.71	8 1/16	1.20	538	0.776	1.82	816	1.176	2.38	1066	1.538	3.54	1590	2.288	4.70	2111	3.038
0.72	8 5/16	1.23	552	0.795	1.86	835	1.202	2.43	1091	1.571	3.62	1625	2.340	4.81	2158	3.110
0.73	8 5/16	1.26	566	0.814	1.90	853	1.228	2.48	1113	1.602	3.69	1656	2.385	4.91	2204	3.174
0.74	8 5/16	1.28	575	0.827	1.94	870	1.254	2.53	1136	1.635	3.77	1692	2.437	5.02	2253	3.245
0.75	9	1.31	588	0.847	1.98	889	1.280	2.58	1158	1.667	3.85	1728	2.488	5.12	2300	3.310
0.76	9 5/16	1.34	601	0.866	2.02	907	1.306	2.63	1182	1.700	3.93	1764	2.540	5.23	2347	3.380
0.77	9 5/16	1.36	610	0.879	2.06	925	1.331	2.68	1203	1.732	4.01	1800	2.592	5.34	2397	3.451
0.78	9 5/16	1.39	624	0.898	2.10	943	1.357	2.74	1230	1.771	4.09	1836	2.643	5.44	2442	3.516
0.79	9 5/16	1.42	637	0.918	2.14	960	1.383	2.80	1257	1.809	4.17	1872	2.695	5.55	2491	3.587
0.80	9 5/16	1.45	651	0.937	2.18	978	1.409	2.85	1280	1.842	4.26	1912	2.753	5.66	2540	3.656
0.81	9 5/16	1.48	664	0.957	2.22	996	1.435	2.90	1301	1.875	4.34	1948	2.805	5.77	2587	3.730
0.82	9 5/16	1.50	673	0.970	2.27	1019	1.467	2.96	1329	1.913	4.42	1984	2.857	5.88	2639	3.800
0.83	9 15/16	1.53	686	0.989	2.31	1036	1.493	3.02	1355	1.952	4.50	2020	2.908	6.00	2692	3.878
0.84	10 1/16	1.56	700	1.008	2.35	1054	1.518	3.07	1377	1.984	4.58	2060	2.967	6.11	2742	3.950
0.85	10 1/16	1.59	714	1.028	2.39	1073	1.545	3.12	1400	2.017	4.67	2096	3.018	6.23	2791	4.020
0.86	10 1/16	1.62	727	1.047	2.44	1095	1.577	3.18	1427	2.055	4.76	2136	3.076	6.33	2841	4.091
0.87	10 1/16	1.65	741	1.066	2.48	1113	1.602	3.24	1454	2.094	4.84	2171	3.128	6.44	2891	4.162
0.88	10 5/16	1.68	754	1.085	2.52	1131	1.628	3.29	1476	2.126	4.93	2212	3.186	6.56	2944	4.240
0.89	10 5/16	1.71	768	1.105	2.57	1153	1.661	3.35	1504	2.165	5.01	2248	3.238	6.68	2998	4.318
0.90	10 5/16	1.74	781	1.125	2.61	1171	1.686	3.41	1530	2.203	5.10	2288	3.296	6.80	3052	4.394
0.91	10 5/16	1.77	794	1.144	2.66	1194	1.720	3.46	1553	2.236	5.19	2329	3.354	6.92	3105	4.473
0.92	11 1/16	1.81	812	1.169	2.70	1212	1.745	3.52	1580	2.275	5.28	2370	3.413	7.03	3155	4.543
0.93	11 1/16	1.84	826	1.189	2.78	1234	1.777	3.58	1606	2.313	5.37	2410	3.470	7.18	3209	4.621
0.94	11 1/16	1.87	839	1.208	2.79	1252	1.803	3.64	1633	2.352	5.46	2450	3.529	7.27	3263	4.698
0.95	11 1/16	1.90	853	1.228	2.84	1274	1.835	3.70	1661	2391	5.55	2491	3.587	7.39	3316	4.777
0.96	11 1/16	1.93	866	1.247	2.88	1292	1.862	3.76	1687	2.430	5.64	2531	3.645	7.51	3370	4.853
0.97	11 1/16	1.97	884	1.273	2.93	1315	1.894	3.82	1714	2.468	5.73	2572	3.703	7.63	3425	4.930
0.98	11 1/16	2.00	898	1.293	2.98	1337	1.926	3.88	1741	2.510	5.82	2612	3.762	7.75	3478	5.008
0.99	11 1/16	2.03	911	1.312	3.02	1355	1.952	3.94	1768	2.547	5.91	2653	3.820	7.88	3537	5.090
1.00	12	2.06	925	1.331	3.07	1377	1.984	4.00	1795	2.585	6.00	2692	3.878	8.00	3590	5.170
1.01	12 1/16	2.09	936	1.350	3.12	1400	2.017	4.06	1822	2.624	6.08	2733	3.936	8.12	3645	5.245
1.02	12 1/16	2.12	952	1.370	3.17	1422	2.049	4.12	1849	2.662	6.19	2778	4.000	8.25	3703	5.332
1.03	12 1/16	2.16	969	1.396	3.21	1440	2.074	4.18	1876	2.701	6.28	2818	4.059	8.38	3761	5.416
1.04	12 1/16	2.19	983	1.415	3.26	1463	2.107	4.25	1908	2.747	6.37	2859	4.117	8.50	3815	5.494
1.05	12 1/16	2.22	996	1.435	3.31	1486	2.140	4.31	1934	2.786	6.47	2904	4.182	8.63	3873	5.578
1.06	12 1/16	2.26	1014	1.460	3.36	1508	2.172	4.37	1961	2.824	6.56	2944	4.240	8.76	3932	5.662
1.07	12 1/16	2.29	1027	1.480	3.40	1526	2.197	4.43	1988	2.863	6.66	2989	4.304	8.88	3986	5.740
1.08	12 1/16	2.32	1041	1.500	3.45	1548	2.230	4.50	2020	2.908	6.75	3030	4.362	9.01	4044	5.823
1.09	13 1/16	2.36	1060	1.525	3.50	1571	2.262	4.56	2047	2.947	6.85	3075	4.427	9.14	4102	5.907
1.10	13 1/16	2.40	1077	1.551	3.55	1594	2.295	4.62	2074	2.986	6.95	3119	4.492	9.27	4161	5.991
1.11	13 1/16	2.43	1091	1.571	3.60	1616	2.327	4.68	2101	3.025	7.04	3160	4.550	9.40	4220	6.075
1.12	13 1/16	2.46	1104	1.590	3.65	1638	2.360	4.75	2132	3.070	7.14	3205	4.614	9.54	4282	6.168
1.13	13 5/16	2.50	1122	1.616	3.70	1661	2.391	4.82	2164	3.115	7.24	3250	4.680	9.67	4340	6.280
1.14	13 5/16	2.53	1136	1.635	3.75	1683	2.424	4.86	2190	3.154	7.34	3294	4.744	9.80	4399	6.334
1.15	13 5/16	2.57	1153	1.661	3.80	1706	2.456	4.94	2217	3.193	7.44	3339	4.810	9.94	4461	6.424
1.16	13 5/16	2.60	1167	1.681	3.85	1728	2.490	5.01	2248	3236	7.54	3384	4.875	10.1	4518	6.526
1.17	14 1/16	2.64	1185	1.706	3.90	1750	2.521	5.08	2280	3.283	7.64	3429	4.940	10.2	4581	6.593
1.18	14 1/16	2.68	1203	1.732	3.95	1773	2.553	5.15	2311	3.329	7.74	3474	5.003	10.3	4623	6.657
1.19	14 1/16	2.71	1217	1.752	4.01	1800	2.592	5.21	2338	3.367	7.84	3519	5.067	10.5	4713	6.786
1.20	14 5/16	2.75	1234	1.777	4.06	1822	2.624	5.26	2370	3.413	7.94	3564	5.132	10.6	4760	6.851
1.21	14 5/16	2.78	1248	1.797	4.11	1845	2.656	5.34	2397	3.451	8.08	3613	5.203	10.8	4850	6.980
1.22	14 5/16	2.82	1266	1.823	4.16	1867	2.688	5.41	2428	3.497	8.15	3656	5.267	10.9	4892	7.045
1.23	14 5/16	2.86	1284	1.848	4.22	1894	2.728	5.48	2460	3.542	8.28	3703	5.332	11.0	4940	7.110
1.24	14 5/16	2.89	1297	1.867	4.27	1917	2.760	5.55	2491	3.587	8.36	3752	5.403	11.2	5027	7.240
1.25	15	2.93	1315	1.894	4.32	1939	2.793	5.62	2522	3.632	8.46	3800	5.469	11.3	5072	7.304
1.26	15 1/16	2.97	1333	1.920	4.37	1961	2.824	5.69	2554	3.678	8.56	3842	5.533	11.5	5162	7.433
1.27	15 1/16	3.01	1350	1.945	4.43	1988	2.863	5.76	2585	3.723	8.67	3892	5.603	11.6	5210	7.457
1.28	15 1/16	3.04	1364	1.965	4.48	2011	2.896	5.82	2612	3.762	8.77	3936	5.666	11.7	5291	7.562
1.29	15 1/16	3.08	1382	1.991	4.53	2033	2.928	5.89	2644	3.807	8.86	3986	5.740	11.9	5341	7.691
1.30	15 5/16	3.12	1400	2.017	4.59	2060	2.967	5.96	2675	3.852	8.99	4035	5.810	12.0	5396	7.736
1.31	15 5/16	3.16	1418	2.042	4.64	2083	3.000	6.03	2710	3.900	9.09	4080	5.875	12.2	5476	7.888

THE JEFFREY MANUFACTURING COMPANY

ESTABLISHED 1877

996 North Fourth Street, Columbus 16, Ohio

BALTIMORE 2, MD., Munsey Bldg.
BECKLEY, W. VA., 403 City Ave.
BIRMINGHAM 3, 2210 Third Ave., N.
BOSTON 16, 38 Newbury Street
BUFFALO 2, Jackson Building
CHICAGO 1, Bell Bldg.
CINCINNATI 2, Carew Tower
Jeffrey Mfg. Co. Ltd., Montreal, Canada
Jeffrey-Galion (Pty.) Ltd., Johannesburg, S.A.

CLEVELAND 15, Hanna Bldg.
DENVER 2, Ernest & Cranmer Bldg.
DETROIT 13, 5808 St. Jean Ave.
HARLAN, Kentucky
HOUSTON 2, TEXAS, City National Bank Building
JACKSONVILLE 2, Barnett Bank Building

The Ohio Malleable Iron Co., Columbus, Ohio
British Jeffrey-Diamond Ltd., Wakefield, England

MILWAUKEE 2, 735 N. Water Street
NEW YORK 7, 30 Church Street
PHILADELPHIA 3, Broad St. Station Bldg.
PITTSBURGH 22, Oliver Bldg.
SALT LAKE CITY 1, 101 W. 2nd South St.
ST. LOUIS, Railway Exchange Bldg.
SCRANTON 3, 122 Adams Avenue

The Galion Iron Works & Mfg. Co., Galion, Ohio
The Kilbourne & Jacobs Mfg. Co., Columbus, Ohio

A complete line of equipment for Water, Sewage and Industrial Waste Treatment as well as Biofiltration Systems for Purification of Sewage and Concentrated Organic Wastes: Bar Screens, Grit Washers (patented), Grit and Sludge Collectors (patented), FLOCTROLS (R) (slow-mixing equipment) (patented), Sludge Elevators, Screenings and Garbage Grinders (patented), Conveyors, Chains, and Bearings.

Catalog No. 833

View at right shows one of the settling basins at the St. Louis City Water Co. Plant equipped with Jeffrey Sludge Collectors—Jeffrey FLOCTROLS in the background.

View at left shows the 26th Ward Treatment Plant, New York City. Each channel is equipped with a Jeffrey scraper type Grit Collector and V-bucket type Elevator.

The Jeffrey Manufacturing Company of Columbus, Ohio, is prepared to grant licenses to all ultimate consumers for a reasonable royalty obtainable upon application, under any or all of its following patents: 1,999,863 — 2,102,990 — 2,160,534 — 2,237,172 — 2,266,097 — 2,268,461 — 2,291,131 — 2,291,641 — 2,324,637.

Jeffrey Mechanically Cleaned Bar Screens

View at left shows 2 Jeffrey coarse, back-cleaned type screens at the 26th Ward Sewage Treatment Works, New York City. Based on a new principle of design this type of Jeffrey Mechanically Cleaned, Coarse Bar Screen is practically fool-proof. Two fine screens are shown in background.

Screen Bars may be of Round or Rectangular cross-section.

Operation by time control is recommended but also can be by differential float. Provision is made for continuous operation if desired.

Jeffrey **JIGRIT** Washer

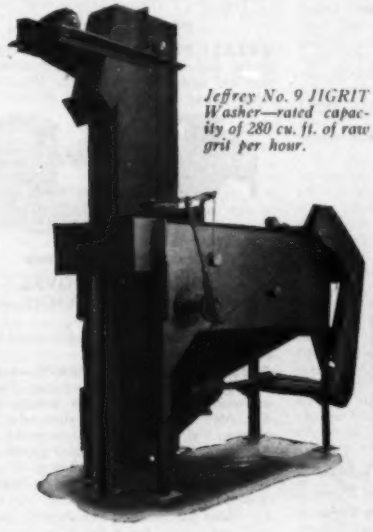
(REG. U. S. PAT. OFFICE)

Jeffrey patented JIGRIT Washer is now built in three sizes ranging in capacity from one ton to fourteen tons per hour, offering these advantages:

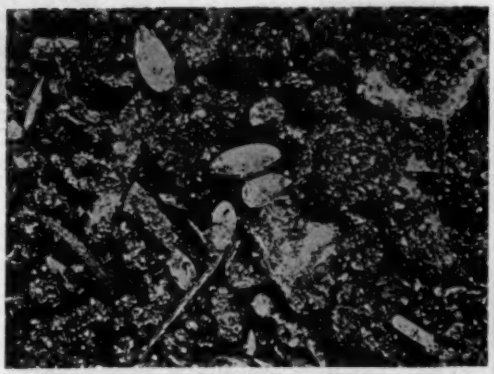
1—Removes 90% of putrescible solids.

2—Washed grit contains no organic seeds or unsightly material—can be used as fill without creating a nuisance.

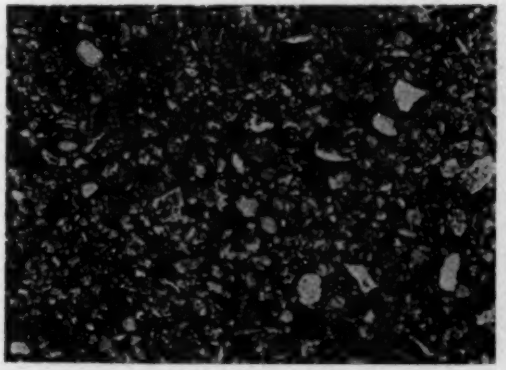
3—Recovers practically all of the +65 mesh grit.



Jeffrey No. 9 JIGRIT Washer—rated capacity of 280 cu. ft. of raw grit per hour.



Magnified view of unwashed sewage grit



Magnified view of washed grit after passing through Jeffrey JIGRIT Washer

AMERICAN WELL WORKS

83rd YEAR
108 North Broadway
AURORA, ILLINOIS

Pumping, Sewage Treatment, and
Water Purification Equipment
RESEARCH · ENGINEERING · MANUFACTURING

Offices: Chicago • New York • Cleveland • Cincinnati • Kansas City • Sales Representatives throughout the World

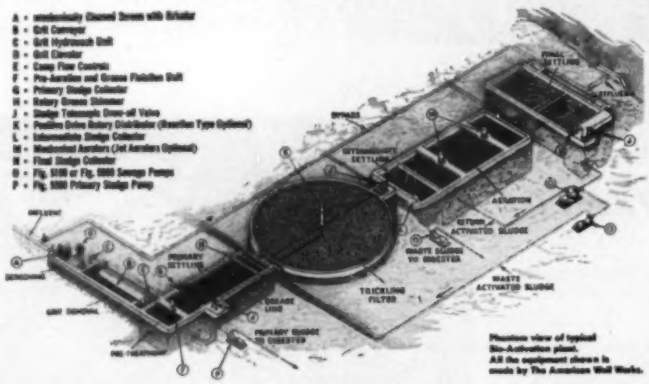
SEND FOR MANUAL NO. 149
"Modern Processes and Equipment for Sewage and Industrial Waste Treatment"

PROCESS... AND EQUIPMENT... FOR SEWAGE AND INDUSTRIAL WASTE

ACTIVITED SLUDGE TREATMENT

BIO-ACTIVATION PROCESS—a patented system utilizing the best qualities of trickling filters and activated sludge. Pre-treatment (pre-aeration and grease flotation) is employed to increase the efficiency of primary settling so as to prevent overloading of secondary treatment. Primary treatment is followed by high capacity filters and short period intermediate sedimentation. Here, initial high removals of B.O.D. are obtained before sewage is passed to aeration tanks where activated sludge is developed. Because of the intermediate filter treatment which considerably reduces the strength of the primary effluent, the liquor can be readily handled by the activated sludge process without the usual upsets caused by exceptional conditions and shock loads.

Send for Bulletin No. 259B



Phantom view of typical Bio-Activation plant. All the equipment shown is made by The American Well Works.

MECHANICAL AERATION—Consists of a circulating pump with downdraft tube and hydraucone assembly. As liquor passes through the pump, fine bubbles of air are drawn in and intimately mixed with the sewage. This mixture is ejected at high velocity across the tank floor. Consequently, entrained air is distributed uniformly across the tank, and fine air bubbles, rising slowly to the surface, supply sufficient oxygen to maintain the activated sludge process. For large installations, "AMERICAN" Aerators are installed in single, large tanks without dividing walls because the pattern of recirculation sets up hydraulic baffles betwten the units, thereby eliminating any possibility of short circuits.

Send for Bulletin No. 265

JET AERATION—Injects an intimate mixture of liquor and finely divided air into the aeration tank. No other method of aeration produces the unusually high rate of oxygen absorption at remarkably low cost. Additional aeration economically provided for existing plants. Present diffuser plate or tube installations easily replaced.

Fully Described and Illustrated in Manual No. 149

ROTARY DISTRIBUTORS—Reaction and Positive Drive Types. The Reaction type is manufactured with 2, 3, 4, or 6 arms. In general, the 3 arm distributor has the advantage of minimum wind effect, low starting inertia, and perfect balance. The Positive Drive type is rotated continuously independent of the sewage flow, by a motorized gear reduction unit. It is used under conditions of low available head and wide variations in flow. "AMERICAN" Distributors are equipped with a patented dual oil seal which eliminates troublesome and costly mercury, protects bearing surfaces, and will withstand at least 10' of water pressure.

Send for Bulletin No. 257A

Send for Technical Supplement TV on Telescoping Sludge Valve

GRIT REMOVAL

AMERICAN CAMP REGULATOR—an adjustable control to maintain velocity of sewage flow thru grit channels at optimum rate, regardless of rate of flow thru plant.

GRIT CONVEYOR—single strand, drag type. Carries grit to hopper for washing and removal.

GRIT HYDROWASH—grit washed free of organic matter by turbulent downflow recirculation of liquor in grit hopper.

GRIT ELEVATOR—tube type, totally enclosed for lifting well-drained grit to desired height. Manual or automatic operation.

Send for Bulletin 249A

American Camp Regulator for Grit Channels

Send for Technical Supplement "CR"

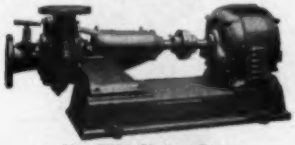
SCREENING

MECHANICALLY CLEANED BAR SCREEN AND GRINDER—designed for wide range of channel widths, settings, and arrangements. Grinder attached to sorting tray . . . shredded screenings returned to sewage flow.

Send for Technical Supplement "MS"

PRE-TREATMENT

GREASE FLOTATION UNIT—removes grease and oils, produces simultaneous aeration and agitation, and oxidizes objectionable odors. *Send for Bulletin No. 260A*



No. 5500 Sludge Pump

SLUDGE REMOVAL

POSITIVE FLIGHT CONVEYORS—for rectangular settling tanks.

CIRCULAR CLARIFIERS—for round settling tanks.

SLUDGE AND SEWAGE PUMPS—Fig. 5500 cutting type primary sludge pump. Fig. 5100 enclosed impeller type raw sewage pumps. Fig. 5600 single vane impeller type sewage pumps. Fig. 3400 recirculation pumps. This line of horizontal and vertical pumps ranges in size from 3" to 18" inclusive, in capacity from 40 to 10,000 GPM, and in head from 5' to 85'.

Send for Bulletins No. 237A, 250A, 253A, 261A

SEWAGE AND SLUDGE PUMPING

By HENRY RYON

Late Senior Engineer, State Department of Public Works, Albany, N. Y.

Part I—Sewage Pumping

DURING the past decades a very marked improvement has been made in the methods of pumping sewage and sewage sludge, and special pumps have been developed for this service. Only a few years ago, however, practically all sewage was lifted with pumps designed primarily for handling water.

The centrifugal dredging pump driven either by a steam engine or an electric motor was used with a fair degree of success at many stations. While this pump would handle sand and gravel satisfactorily, rags would wrap themselves around the impeller and necessitate frequent cleaning of the pump either through hand holes in the volute or by the removal of the side of the case. It was not very efficient and the head was limited. The smaller and higher speed centrifugal pump, used successfully for pumping water, gave more trouble, due to clogging, when used for pumping sewage, than the dredging pump.

Reciprocating pumps were used in many cases. These pumps clogged about as easily as the centrifugal pumps; and, if there were any sand or grit in the sewage, gave trouble due to the scoring of cylinders. At one or two large stations the crank and fly wheel pump was used and operated satisfactorily principally because of its large size. The ordinary duplex steam pump served in a few cases. The single acting triplex pump, equipped with ball valves, although not entirely free from clogging, proved to be the most satisfactory of the reciprocating pumps and was used, and is still being used, successfully for pumping both sewage and sludge. Its cost is, however, greater than that of a centrifugal pump and it is rather noisy. It is worth noting that the design of the most modern reciprocating sludge pumps have apparently been copied from the old single acting triplex pump.

At almost all of the old pumping stations the sewage was passed through bar or mesh screens to remove the rags and other solids from it before it reached the pumps. The cleaning of the screens always proved a laborious and unpleasant task, and did not entirely do away with the necessity of cleaning the pumps.

The Pneumatic Ejector

In order to eliminate the trouble of cleaning screens and pumps, the pneumatic or compressed air ejector was developed. This device, which was first used about fifty years ago, operates by allowing the sewage to flow into an iron or steel chamber and, when the chamber is full, automatically admits compressed air above the sewage thus forcing it out through the discharge line. The mechanism operates very successfully, and stories are told of ejectors having been lost for several years and when rediscovered were found to be operating satisfactorily. It requires, however, air compressors, air tanks, and other appurtenances which make the first cost and also the maintenance expensive. In addititon to this, the efficiency is very low. The overall or wire to water efficiency when the compressors are operated by electricity vary generally from 10 to 20 per cent. At present, due to the improvements in the design of centrifugal pumps, ejectors are being used less and less except in the very small stations or for sludge and screenings handling.

Pump Impellers

The improvement in the centrifugal sewage pumps has been largely in the design of the impellers or runners. There are, in general, two types of pump impellers, the open and the closed. The open impeller gives larger water ways with the same size casing, but solids clog between the impeller and the casing and rags wrap around the impeller blades. Increasing the clearances to reduce clogging, of course, reduces the efficiency and does not prevent rags from stopping the flow. Open impellers, generally with only two blades, serve well in small sump pumps and also in sewage pumps of small capacities where a closed impeller small enough to give the desired capacity would not pass solids of any size. In most cases, however, the closed or semi-enclosed impeller is to be preferred.

In the design of closed impellers for handling sewage, the water passages have been made wider than in water pumps, all sharp edges and turns have been carefully avoided, thus reducing the chance of clogging to a minimum. As a general rule pumps with impellers of this type will pass solids having diameters about one pipe size smaller than the size of the pump. One manufacturer is producing a pump with a worm feed to force the solids to the impeller of the pump and also cut and crush them against hard steel bars, running longitudinally of the screw case. Pumps of this type are giving satisfactory service in several western stations. A rather unique impeller is used in some English pumps. The impeller is open on the suction side and the blades are considerably wider at the shaft than at their ends. The edges of the blades pass very close to bars set on the inside of the case and macerate the solids entering the pump.

It is customary to require the impellers of the pumps to be made of bronze but with ordinary sewage there seems to be no advantage in the use of bronze as compared with that of cast iron. A few pumps have been installed having cast iron impellers coated with enamel and they are said to be giving satisfactory results. The manufacturers claim a slightly higher efficiency for this impeller than can be obtained with the bare metal impeller.

Submerged Vertical Pumps

For the smaller installations probably the submerged vertical centrifugal pump is the most commonly used. The sump may be made of cast iron or steel or may be of concrete. The motor and pump are both supported on a removable iron cover so that the pump can be lifted out of the sump for cleaning and repairs. Enough head room must, of course be provided to allow the suction to clear the top of the sump when the pump is lifted out. It is also desirable that the discharge be brought up through the same plate so that it may be easily disconnected. In unheated pump houses, however, it is sometimes impossible to do this without danger of the sewage in the discharge line freezing. Where short separate discharges can be used, freezing can be avoided by omitting the check valves and allowing the sewage in the discharge pipe to flow back into the sump after each discharge. If screens are to be omitted it is usually advisable to provide a pump not smaller than 3 inches in size. Such a pump will have a capacity of from 50 to 300 gallons per minute, depending upon design of the impeller and the speed of the motor.

Float Controls

Sewage pumps are usually automatic in operation and the arrangement of the float control deserves more attention than it generally receives. The float may be connected to the electric switch either by a push rod or by a chain running over pulleys with a counterweight to balance the float. Either method operates satisfactorily if properly arranged. Floats that hang unprotected in the sump are apt to be moved sideways by the motion of the sewage causing the chain or rod to bind, or the rod to bend, making the float inoperative. In some designs the rod has a guide at the bottom to prevent such motion, but if the rod sticks in the guide or leaves the guide its inaccessible location makes it very difficult to repair. The lever float, sometimes used, has generally proved very unsatisfactory for sewage because rags are apt to collect on the lever and prevent its operation. As in the case just mentioned it is generally very difficult to reach such a float to repair or adjust it. The best design is one in which the float is arranged in a tube to guide and protect it and a removable cover plate provided over the tube so that the float can be readily lifted.

Pumps in Separate Dry Wells

For the larger pump stations, and even in the small stations when the conditions will permit, the installation of the pumps in a separate dry well makes the most satisfactory arrangement. This leaves the pumps and their appurtenances accessible for repairs and adjustment. The pumps may be either vertical or horizontal. The vertical pumps have the advantage of requiring a smaller pit and of keeping all electrical equipment above ground and free from danger of flooding, while on the other hand the horizontal pumps are easier to keep in adjustment and alignment. If the pit is deep, one or more guide bearings will probably be required on the shafts of vertical pumps as it is necessary to divide the shafts into lengths of not more than 8 or 10 feet to prevent vibration. I-beams are usually set across the pit to carry these bearings, but it is often difficult to set these beams so as to get a perfect alignment of the shaft. In order to avoid this difficulty, several manufacturers are building steel lattice frames extending from the motor to the pump. The pump and motor can then be aligned at the factory with very satisfactory results. In some cases the motor, shaft and pump have been attached to a heavy channel, aligned at the factory, and shipped as a unit.

With the pumps in a separate dry well it will usually be necessary to provide some means for removing seepage from the well. This may be done with a separate automatic sump pump, or, if a cheaper installation is desired, a small valved connection may be made from the suction of one of the main pumps to a sump and the sump emptied at intervals by closing the main suction valve and opening the connection to the sump.

Design of Suction Well

The shape of the bottom of the suction or wet well is of considerable importance. If it is left flat, solids will collect in the bottom and ferment giving rise to unsatisfactory conditions. The floor of the wet well

should have a steep slope toward the pump suctions.

In some cases where the sewage is warm and contains considerable grease, trouble has been experienced due to the grease congealing on the walls of the well and then breaking loose in large pieces and entering the pumps and clogging them. The openings in the impellers of 4-inch horizontal sewage pumps have been stopped several times by this cause.

Bearings and Glands

There does not appear to be very much choice in regard to the type of bearings used, ball bearings and sleeve bearings seem to serve equally well provided they are properly oiled. Ball bearings are, however, usually provided to take the thrust or to carry the weight of the impeller of a vertical pump. The part of the shaft that passes through the stuffing box should be of bronze or covered with a bronze sleeve otherwise difficulty will be experienced in keeping the packing in condition. This stuffing box is usually provided with a water seal, although grease seals and special devices are sometimes used. In water pumps the water for the seal is usually taken from the volute of the pump. With sewage pumps, however, this is not advisable for the solids in the sewage are apt to clog the small passages and also because the grit in the sewage will reach the packing and cut the pump shaft. To avoid the possibility of the pollution of the clear water with sewage, the water must usually be taken from a constant level tank supplied from the water lines and not directly from the lines themselves. With double suction and open impeller pumps, if there is a suction lift, there will probably be vacuum on the pump side of the stuffing box and the water seal serves to prevent the entrance of air. With end suction pumps, with enclosed or semi-enclosed impellers, there may be a pressure on the pump side of the stuffing box. The water seal then serves to prevent the grit in the sewage from reaching the packing and cutting the shaft. The pressure on the water seal should of course be greater than the sewage pressure.

Centrifugal sewage pumps will operate satisfactorily if set as high as 15 feet or even a little more above the sewage level, but in such cases special priming devices must be provided for the ordinary method of priming, by filling the suction from the discharge line, cannot be used because it is inadvisable to attach a foot valve to the bottom of the suction. While special priming devices can be used, it is better, if possible, to locate the pumps below the level.

Efficiency and Head

The non-clogging centrifugal pumps will generally give over all efficiencies varying from 35 per cent for the smaller sizes to 65 per cent for the larger pumps. The lift of sewage pumps is usually low and most of the pumps are designed for heads under 40 feet but pumps can be obtained that will lift sewage against heads as high as 75 or or even 100 feet. Beyond this head two stages are needed, but the ordinary type of multi-stage pump used for water cannot be used because of the many sharp turns and the narrowness of the water passages. At a station where it was necessary to raise sewage 180 feet, two pumps connected in series on the same base, with the motor between them, have been used successfully. The overall efficiency of the unit was found on test to be 35 per cent.

Hydraulic Characteristics of Centrifugal Pumps

With centrifugal pumps, careful attention must be given to the hydraulic characteristics of the pumps in designing a pumping station, particularly if the discharge line is of any considerable length.

If an engineer desires a pump to deliver 300 gallons per minute against a head of 20 feet he is very apt to add a little to the head for safety and specify that the pump shall deliver 300 gallons a minute against a head of say 21 feet. A typical 4-inch pump will meet these specifications almost exactly, and will require about 2¼ horsepower to operate it and, a 3-horsepower motor will serve satisfactorily. If, after installation, it is found that the actual head is only 18 feet instead of 21 feet, due to some unforeseen condition or due to the fact that the engineer figured his friction for 10 year old pipe and the pipe is actually new pipe, this pump will deliver 600 gallons per minute instead of 300 gallons per minute and will require 3½ horsepower. The 3-horsepower motor will in that case be overloaded. Conditions similar to this occur very frequently and it is best in all cases to require the motor to be of sufficient size to operate pump without overheating at any head between the maximum and zero.

When two or more pumps are connected to the same discharge line, the reverse condition often occurs. If two pumps, having the characteristics mentioned above, are connected to a single discharge line, one pump operating alone will discharge 300 gallons per minute. When both pumps are put in operation the friction loss in the discharge line will of course increase. With the particular 4-inch pump just mentioned, if this increase is only about 1½ feet (from 21.0 feet to 22.6 feet) the discharge of each pump will be reduced to 200 gallons a minute or the total discharge of the two pumps will be about 400 gallons per minute or only slightly greater than the discharge of one pump. For this reason it is often found desirable, especially with long discharge lines, to arrange the controls so that one pump will shut off entirely and the second pump, designed for a larger capacity and a little higher head, will start when the sewage flow exceeds the capacity of the first pump.

Multispeed motors are sometimes used to meet these conditions but such motors operate only at certain fixed speeds and it is generally difficult to design the pumps to obtain the desired capacities at these motor speeds. Any desired speed may be obtained by using variable speed motors, but if this is done the losses in the resistance greatly reduce the overall efficiency of the pumping equipment.

At the Harlem Valley State Hospital pumping station which contains 8 4-inch 450 gallons per minute pumps, a special arrangement was used. As each additional pump starts the friction loss in the discharge line increases approximately 6 inches. The controlling float and float switches are so arranged that as each additional pump starts the sewage level in the suction well is automatically allowed to rise 6 inches. Thereby, the total head, and consequently the discharge of each pump, always remains the same and has proved a distinct advantage.

Suction Line Difficulties

There are several matters in connection with the arrangement of centrifugal pump suction lines, particularly where there is some suction lift, which, while they seem very simple, have caused engineers and operators considerable trouble. There must be no high point in any suction line where air or sewage gases may accumulate. When the pump is started the accumulated air will expand, flow to the pump, and stop its operation. The reducer at the pump must for this reason always be an eccentric reducer with the flat side up. Connections to a common suction header must for the same reason be made at the top of the header and not at the center of the side. In some extreme cases it has even been found necessary to place the suction valves horizontally so as to avoid the accumulation of air in the bonnets. Common suctions, that is, single suction lines to which two or more pumps are connected, are a sources of trouble in many cases where there is a suction lift, and wherever possible should be avoided. It is often difficult in such cases to make each pump take its share of the load. When one pump is in operation it is often impossible to start the second without shutting down the first and starting both together. A slight leak in the stuffing box of one of the idle pumps will many times admit enough air to interfere with the operation of the other pumps. Even when the pump that is not to be operated is entirely shut off, air will frequently accumulate in the riser from the common suction to that pump and will expand when the other pump or pumps are started and enter them and prevent them from operating.

Part II—Sludge Pumping

Pumps designed for moving or lifting sewage sludge may, in general, be divided into two distinct classes, displacement pumps and centrifugal pumps. Since these two classes differ radically in their design and operation and present entirely different problems for those in charge of them, it is necessary to consider them separately. The advantages and disadvantages of each class are matters which engineers and operators are not entirely agreed upon. Displacement pumps are unquestionably more easily primed than centrifugal pumps when there is a suction lift and will probably handle small quantities of sludge more readily than centrifugal pumps, but beyond this it is doubtful whether the advocates of either class will admit the superiority of the other.

Displacement Pumps

The modern displacement pumps used for handling sludge are always of the single acting reciprocating type, and are usually electric motor driven plunger pumps having one, two or more cylinders. The makes most commonly used generally have cylinders about ten inches in diameter and strokes adjustable from about two to five inches. The pumps are connected to the motors by gears, belts or chains and the motion transmitted to the pistons by walking beams or eccentrics.

Transmission

Certain matters in connection with the transmission are, however, of importance. If it is desired to have the pump run smoothly it is usually best to keep the speed of the main pump shaft below about thirty-five revolutions per minute. This gives a piston speed of thirty feet a minute or less, a low figure as compared with the usual figures for water pumps; but the strokes of these sludge pumps are very short and the frequency of the reversals seem to be of more importance than the actual piston speed. Pumps of this type are generally arranged so that the length of the stroke can be changed by shifting an eccentric or, which amounts to the same thing, altering the length of the crank arm. This makes it possible to obtain several different rates of discharge, but experience indicates that the use of the shorter strokes is not always entirely satisfactory. The pumps in most cases do not operate as smoothly with the short strokes as with longer ones, the slip

is greater and the efficiency lower. The use of multi-speed motors and variable speed transmissions, although more expensive, afford a more satisfactory and efficient method of changing the pump capacities to suit the conditions, and where available should be used in preference to changing the length of the stroke.

Packing

Like all reciprocating pumps the sludge pumps must be packed to prevent leakage between the pistons and the cylinders, and this packing is one of the most frequent causes of trouble in the operation of the pumps. The packing may be either on the cylinder or the piston. Generally it consists of from 4 to 6 rings of ½ inch to ¾ inch packing held in place by an adjustable metal ring or gland. If the packing is too tight, scored pistons or cylinders and broken shear pins will be the result. If the packing is too soft, too loose or improperly placed it will leak, and since the pumps are outside packed this means that the pumps and probably the floor around them will soon be covered with sludge which does not add to the attractiveness of any sewage treatment plant. Opinions differ as to the most satisfactory type of packing. Generally a square braided flax packing serves as well as any. A graphited packing may be desirable to prevent unsatisfactory conditions due to rust where the pumps stand idle for a considerable time. Rawhide packing is satisfactory but does not seem to be necessary except with certain chemicals. The packing must fit and must be properly placed. In cutting the packing it is well to use a template into which a piece of packing exactly the length of one ring can be fitted. In this way each ring will have the same length and the same bevel. The method of oiling the packing varies with the make of the pump. Generally it is found that a fairly heavy oil such as a good grade of cylinder oil gives the best results. Oils known as "500 W" and "Marine Pump Oil" are in common use. A light oil disappears very rapidly. Under continuous operation the packing will usually last about 3 months, but under intermittent operation it may last a year or two. Manufacturers have recently been giving more attention to the finishing of the pistons and cylinders, in some cases grinding them. This has made it easier for operators to keep sludge from leaking between the pistons and cylinders but has not done away with the necessity for careful packing.

Valves

Each cylinder of a reciprocating pump necessarily has an inlet valve and a discharge valve. These valves may be weighted flap valves or ball valves. Each type has its advocates although at present the ball valves seem to be preferred by most operators. Spring loaded poppet valves which operate satisfactorily in water pumps obviously cannot be used for liquids containing an appreciable amount of solids. No matter which type is used the valves will require some attention from the operator. With raw sludge the valves may require cleaning from two to three times a day to two or three times a week. If the pump is handling activated or secondary tank sludge, cleaning will of course be required less frequently. Fibrous material will collect under the hinges or flap valves and rags will accumulate under ball valves holding the valves off their seats and rendering the pump inoperative. Metal flap valves wear at the hinges so that the flap will not seat properly and soon require replacement. Valves of rubber with rubber hinges clog less frequently than metal valves because of their smoother surfaces, but the rubber hinges are inclined to swell and split and it is difficult to turn them back for cleaning. Ball valves are usually of rubber moulded on an iron core. If they are to operate satisfactorily, careful attention must be given to the quality of the rubber, the balance of the valve and the weight of the core. Valves made of a poor quality of rubber will sometimes swell and stick, and cases are on record where the rubber has softened so as to allow the ball to be forced into the piping stopping the pump. The valve must balance or the ball will always seat at the same point and wear rapidly. The weight of the valve must be suitable for the conditions under which it will operate.

Pounding or Knocking

One of the most frequent complaints heard regarding the operation of reciprocating pumps is that they knock or pound. This is due to various causes. Since sludge lines are usually comparatively short, the high water hammer stresses sometimes encountered at water pumping stations are seldom of importance, but the flow of liquid in the suction and discharge lines must be stopped and started with each stroke (single cylinder pump with no air chamber), the valves must close and in doing so strike the seat, and each stroke causes a reversal of stresses in the piston, the crank and the connecting mechanism. These conditions cause pounding which cannot in all cases be entirely eliminated. The subject is too complicated to be discussed in detail here.

The stresses and pounding due to starting and stopping the flow in the discharge line can be generally alleviated by the use of an air chamber, but the air chamber must be large to be of any value. The same thing is true of the suction line, although an air chamber is not so frequently used at this point. One manufacturer provides a small air inlet valve on the suction of the pump which if properly adjusted seems to make the pump operate more smoothly, but of course somewhat reduces its capacity and efficiency.

Valve slam is sometimes due to the fact that the direction of flow through the valve reverses and acquires considerable velocity before the valve closes. This velocity may then carry the valve to its seat rapidly enough to cause a heavy blow when the motion of the valve and the liquid is suddenly stopped. This reverse flow of water through the valve is of course slippage and reduces the efficiency of the pump as well as causing valve slam. The valve should, for these reasons, be heavy enough and so arranged as to close as quickly as possible, and yet not interfere with the operation of the pumper by reducing the area of the ports.

The knocks due to the reversal of stresses in the different parts of a pump are the same as those which occur in any reciprocating machine. If there is any lost motion in a main bearing, eccentric, wrist pin or other part there will be a knock each time the stresses are reversed. The remedy is obvious. All bearings must be properly adjusted and kept properly lubricated.

Centrifugal Pumps

Centrifugal pumps, if they are to handle sludge successfully, must pass solids without frequent clogging. This makes it necessary to use end suction pumps at least 4 inches in size with as few bends and sharp corners in the liquid passages as possible. The impellers usually have only two blades with long sweeping curves and are either fully enclosed or have a shroud on one side. Open impellers clog very rapidly when the liquid contains rags. Even with these precautions, it is generally desirable to have hand holes or other means of access to the interior.

One pump manufacturing company equips its centrifugal sludge pumps with a screw to force the sludge into the pump and to macerate the solids as they enter. Pumps of this type have been in operation at a number of plants for several years. Similar devices are being made by some other manufacturers but have not as yet come into extensive use.

Capacity and Regulation

A 4-inch centrifugal pump will readily discharge 100 gallons a minute and in some cases as low as 50 gallons a minute, but if capacities below this are necessary some difficulty is apt to be experienced unless provision is made for reducing the speed below that which can be obtained by a direct connected motor. Variations in head, of course, cause variations in the capacity of a centrifugal pump and if a definite quantity of discharge is required some method must be provided to compensate for these variations. In many plants it is necessary to change the quantity of sludge delivered from time to time and provision must be made for so doing. Theoretically, throttling might accomplish these ends, but throttling is not desirable when pumping sludge. If careful adjustment of the quantity of sludge delivered is necessary the only practical method of regulation seems to be to change the speed of the pump. Variable and multi-speed motors will do this within limits but are not as satisfactory as some of the variable speed transmissions available. These transmissions, while expensive, make it possible to obtain almost any capacity within the limits of the pumps. It must not be forgotten, however, that a centrifugal pump will give its highest efficiency at one definite speed and capacity and that as the speed and capacity are changed the efficiency may fall off rapidly. This is naturally of more importance when the pumps are in continuous operation than when they are operated intermittently.

Priming and Seals

Centrifugal pumps will not handle air, and when they are used careful consideration must always be given to priming and to the elimination of air pockets in the suction line. To facilitate priming, centrifugal pumps should if possible be set below the surface of the liquid in the suction well. If the pump must be set above the level of the liquid some means of priming must be provided. Foot valves which are often used with water pumps will not serve satisfactorily with pumps handling sludge. Vacuum systems are available and operate satisfactorily if kept in condition, but mean added expense of installation and more equipment for the operator to maintain.

The impeller shaft of every pump of this kind must pass through the pump casing and therefore requires a stuffing box to prevent leakage. On water pumps these stuffing boxes are provided with water seals and the water taken from the pumps. The material handled by a sludge pump is not, however, suitable for the seals and water must be obtained from some source. A direct connection to the water system cannot be used due to the danger of polluting the water supply with sludge. If the building is high enough a small tank fed over the top and controlled by a float valve may be used as a source of water. The height of the tank must be greater than the discharge head of pump or the sludge will be forced into the packing and probably result in the scoring of the shaft. If the tank cannot be set high enough, a pump may be used to supply water to the seal.

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TECHNICAL INFORMATION

W&T representatives will gladly discuss any specific sewage chlorination problem. Technical bulletins on the many phases of sewage chlorination and W&T Chlorinators will be sent free on request.

PRIMARY DEVICES AND METERS FOR WASTE FLOW MEASUREMENTS*

By HOWARD O. HITE

Engineer, Brown Instruments Division, Minneapolis-Honeywell Regulator Co., Philadelphia, Pa.

FLOW meters for waste measurement fall into two categories. The first class, differential head meters, is used for measurement in completely filled pipes and includes such primary devices as orifice plates, nozzles, and venturi tubes and a suitable differential pressure meter. The second category, known as head-area meters, is used for measurement of flow in open channels and partially filled pipes. Examples of this type meter are weirs and Parshall flumes.

As complete coverage of the subject would be exceedingly lengthy, this paper merely points out the advantages and limitations of each of the most commonly used devices as an aid in the selection of meters for specific applications.

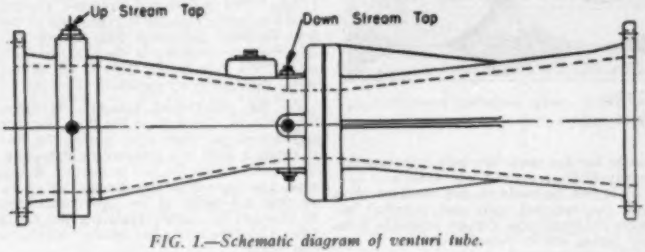

FIG. 1.—Schematic diagram of venturi tube.

Differential Head Devices

The differential head meter, as previously mentioned, requires that the pipe be kept filled with fluid for satisfactory operation. All primary devices for use with such meters are basically differential pressure producing resistances. As the fluid enters the resistance, the velocity is increased, with a loss in static pressure. It is this drop in static pressure that is measured as an indication of flow.

Venturi Tube

The venturi tube (Fig. 1) is the oldest of the modern primary elements. The designs used today are essentially the same as those used by Clemens Hershel in 1887. The venturi tube consists of a conical reducing section, a cylindrical throat section, and a diverging exit cone. The transitions from the entrance cone into the straight throat are rounded off by an easy tangential curve to avoid the resistance caused by a sharp corner and also preclude the possibility of cavitation. The differential pressure is measured between taps located slightly upstream of the entrance cone and at the throat.

When the venturi is used with clean fluids, a piezometer ring is usually used at both of these points to obtain the average static pressure at each point of measurement. For many sewage and industrial waste applications the piezometer rings are replaced by a single tap at each measurement point. With this arrangement, clear liquid purges may be used to keep the taps open. An alternate scheme, which is often used, is a manually operated cleaning valve.

The entrance cone generally has an included angle of 21° and the exit cone an included angle of 7°. This design gives the optimum pressure recovery. Usually about 80 to 90 per cent of the pressure drop at the throat is regained. Other angles have been used to reduce the length and weight of tubes, but this is done at a slight reduction of the pressure recovery characteristics.

Cast iron is the most common metal used for venturi tubes. However, special tubes of other materials may be obtained to overcome corrosion problems. Brass, bronze, stainless steel, concrete, and even rubber-lined tubes have been supplied.

The venturi tube has the following advantages over other differential devices:

1. Tapered approach and exit cones give lowest pressure loss.
2. For the same head differential and diameter, flow rates will be approximately 50 per cent higher than for an orifice.
3. There are no pockets where suspended particles in the solution may accumulate.
4. Long runs or straight pipe are not required.

The principal limitations of a venturi are its relatively high cost, large size, and lack of flexibility of range.

Flow Nozzle

The flow nozzle (Fig. 2) consists essentially of the entrance cone and throat section of the venturi, but has no recovery or exit cone. The upstream or high-pressure tap is made through the pipe wall at approximately one pipe diameter from the entrance. The low-pressure or downstream tap is located at the point of smallest jet area. The nozzle, which can be manufactured from most any material, has the following advantages:

1. It can measure 50 per cent more flow than an orifice.
2. Shorter meter runs are permissible than for an orifice.
3. It can be simply installed between pipe flanges.

The disadvantages are:

1. Although its cost is below that of a venturi, it is still much higher than that of an orifice.
2. Experimental work remains to be done in order to determine complete coefficients.
3. Not suitable for liquids containing solids in suspension.

Orifice

The orifice is probably the oldest device for measuring or reglating fluid flow. Records show that it was used to measure flow to householders in Rome during Caesar's time. Nevertheless, it did not receive real recognition as a commercial primary element until about the time of World War I.

The most common type of orifice is the concentric orifice. It consists of a thin flat

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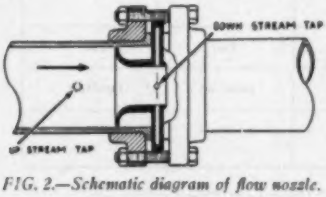

FIG. 2.—Schematic diagram of flow nozzle.

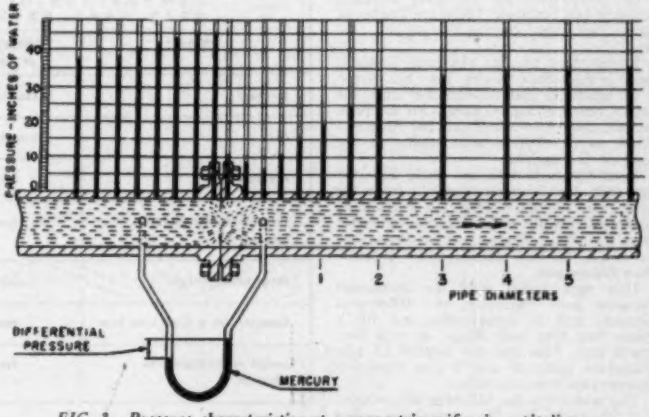

FIG. 3.—Pressure characteristics at a concentric orifice in a pipeline.

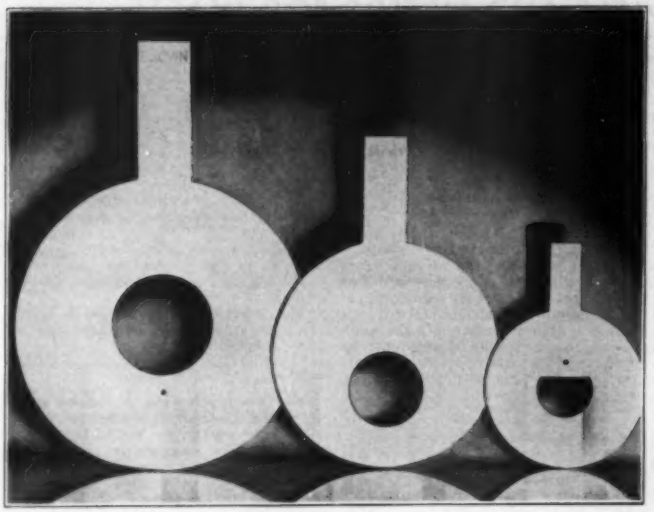

FIG. 4.—Types of pipeline metering plates now under study, including concentric, eccentric, and segmental orifices.

plate with a round hole, mounted between standard pipe flanges so that the hole is concentric with the pipe.

The Fluid Meters Committee of the American Society of Mechanical Engineers has spent considerable time and money studying the characteristics of flow through thin plate orifices. With the data obtained, orifice plates can be calculated and installed to measure flow with accuracy equal to that of the best venturi tubes. Orifice plates are usually made of stainless steel, although other materials such as glass and monel metal have been used.

Fig. 3 shows the pressure characteristics at the orifice. The pressure builds up slightly in front of the orifice, then drops suddenly on downstream side and continues to drop for a short distance along the pipe before the recovery starts. The point of minimum pressure and, incidentally, maximum velocity, is known as the vena contracta. It can be seen that the points at which the differential pressure measurements are taken are critical. For this reason, the Fluid Meters Committee has established orifice coefficients for the three standard pressure tap locations. These are known as flange taps, vena contracta taps, and pipe taps.

Flange taps are, as the name implies, made in the orifice flanges. They are spaced 1 in. upstream and downstream from the orifice. Standard tapped flanges are available and are simpler to install than the other two types, as no drilling and tapping of the pipeline is required.

Vena contracta taps are made with the upstream tap 1.0 pipe diameter from the orifice and the downstream tap at the vena contracta, usually about 0.5 pipe diameter from the orifice. These are not quite as easy to install, but are slightly more accurate than flange taps.

Pipe taps utilize only the permanent pressure loss. Therefore, the differential pressure will be considerably less for a given flow than with flange or vena contracta taps. Pipe taps are located 2.5 pipe diameters upstream and 8 pipe diameters downstream from the orifice.

The orifice has the following advantages:

1. The cost is low. For example, an orifice plate for a 6-in. line costs about $17. A nozzle for the same line will cost approximately $135; a venturi, about $375.

2. It can be made in any machine shop with conventional tools and installed between standard pipe flanges available from any piping supply house.

The disadvantages are:

1. The pressure loss is higher than that of a venturi.

2. Flow capacity is less than for a venturi or a nozzle; the exception to the rule is in the case of pipe taps, where the flow capacity is comparable to a venturi.

3. It is not suitable for liquids carrying solids in suspension.

4. Long pipelines are required in front of the orifice.

Work is now being carried on by the Fluid Meters Committee to determine coefficients for segmental and eccentric orifices (Fig. 4). In these orifices the opening is placed tangent to the bottom of the pipe. When these data become available the limitations regarding measurement of suspended solids with the orifice plate should be removed.

Fig. 5 shows a comparison of the principal application considerations for each of the primary elements discussed. Although it may appear that the principal advantage of the orifice over the other forms is its low cost, by proper design of orifice and selection of meter range the other objections of lower capacity and higher pressure loss can be overcome.

Differential Head Meters

All of the meters for measurement of flow through these primary elements are primarily differential pressure measuring devices. As such, they must contend with the fact that flow through any of these primary devices is proportional to the square root of the differential pressure.

The simplest type of secondary instrument is a variation of the common mercury manometer. A typical meter of this type is shown in Fig. 6. It consists of a float chamber, a range tube, and a connecting U-tube. The differential pressure created by the primary element is connected to the float chamber and range tube. In this design the float chamber is the high-pressure side of the manometer. This is not necessarily the case in all meters of this type.

As the differential pressure increases, the mercury level falls in the float chamber and rises in the range tube, causing the float to rotate a shaft in a pressure-tight bearing. This shaft moves the pen or pointer. Range tubes are made in an interchangeable series, so that the range of the instrument may be changed by merely replacing the range tube. This type meter has square-root charts and scales.

Other types of secondary instruments use cams, shaped range tubes, shaped bells, or other mechanical and electrical means to extract the square-root function and use uniformly graduated charts. Square-root charts give best readability and accuracy at the high end of the scale, whereas linear charts have improved readability at the low end. The choice of chart is primarily a matter of personal preference.

Secondary meters are available in a wide variety of forms. These include electric and pneumatic transmission, or direct-connected instruments. Indicating, recording, integrating, and controlling instruments can be obtained for almost any combination of these functions.

COMPARISON OF DIFFERENTIAL HEAD TYPE PRIMARY ELEMENTS

PROPERTY	CONCENTRIC ORIFICE	VENTURI	NOZZLE
Accuracy	Excellent	Excellent	Good
Cost	Excellent	Poor	Fair
Pressure Loss	Poor	Good	Poor
Suitability for Solids in Suspension	Poor	Good	Fair
Range Changing Ease	Excellent	Poor	Poor
Capacity for a Given Line Size	Good	Excellent	Excellent
Length of Straight Pipe Required	Poor	Excellent	Excellent

FIG. 5.—Comparison of Differential Head Type Primary Elements.

In specifiying instruments for a given application, the meter manuafcturer will insist on knowing all the conditions involved. If the application requires special consideration with respect to corrosion, head loss, or solids in suspension, he will advise the best form of primary element and meter for the particular application.

Head-Area Devices

In head-area meters, both the cross-sectional area of the stream and the head are variables, but not independently of each other; the area is a function of head. These meters are limited to measurement of liquid flow in open channels.

Parshall Flume

The most widely used primary device of the head-area meter type for sewage and industrial wastes is the Parshall flume, (Fig. 7). It consists of an entrance section with converging walls and level floor, a throat section with parallel walls and downstream sloping floor, and an exit section with diverging walls and a rising floor. If the flume is properly installed in a channel, the rate of flow through the flume can be determined by a single measurement of the head or level made at a point one-third of the length of the inlet section from the entrance. A stilling well should be provided at the point of measurement to permit more accurate reading of the head.

The Parshall flume has the following advantages over weirs or other head-area meters:

1. It is easy to construct and may be made in a variety of materials (wood, sheet metal, or poured concrete).

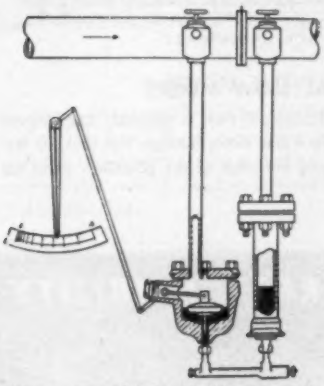

FIG. 6.—Simple differential pressure flow meter.

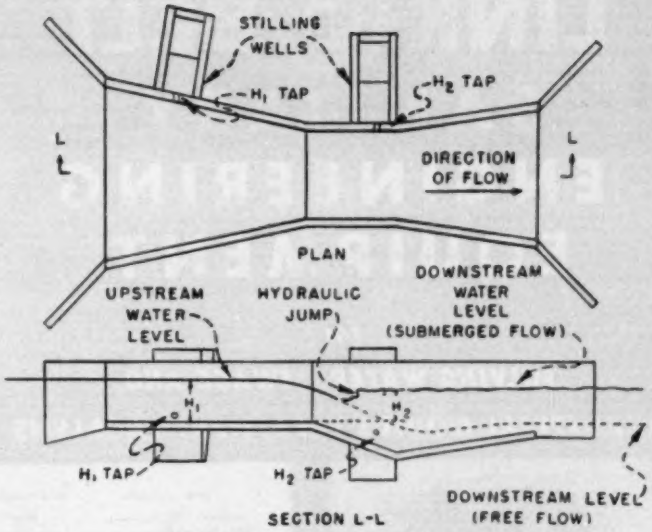

FIG. 7.—Basic elements of Parshall flume.

Although the weir is most accurate of the head-area meters, it has several limitations as a primary element for industrial use:

1. It requires construction of a weir box to obtain the proper flow approach to the weir.
2. Sediment in the fluid will settle in the weir box, with adverse effects on the weir calibration.
3. The loss of head through the weir will be equal to the head measured.

Kennison Nozzle and Parabolic Flume

Two other head-area devices in use today are the Kennison nozzle and the parabolic flume. They are both suitable for measurements of fluids containing solids in suspension. Like weirs, however, they must operate with a high loss of head compared to the Parshall flume.

Head-Area Meters

The measuring devices used for head-area meters are generally float actuated. Motion of a float riding on the liquid surface in the stilling well is transmitted to the instrument by a cable or tape. The instrument usually incorporates a cam or other device that extracts the proper function to give a uniform flow scale. These instruments are also available in the recording, indicating, and integrating forms of the differential head meters.

2. Solids in suspension are readily carried through the flume and do not affect the measurement accuracy.
3. Wide variations in capacity are possible. Flumes have been made with throat sections as small as 3 in. and as large as 50 ft.
4. The loss of head required for flow measurement is extremely small.

The only disadvantage of the Parshall flume is that its accuracy is not as high as that of a well-made and properly installed weir. Accuracy is generally stated to be within 2 to 5 per cent.

Weirs

A weir is a dam in a stream with a notch cut in the crest. The most common notches are rectangular, triangular, and a combination of the two, trapezoidal. Rectangular weirs generally are used for large flows where the variations between maximum and minimum flow are not too wide. The triangular weir is used for accurate measurement of small rates of flow and is particularly sensitive to changes in rate of flow at the low end of its range. The trapezoidal, or Cipolletti weir combines the features of both, having wider range ability than either.

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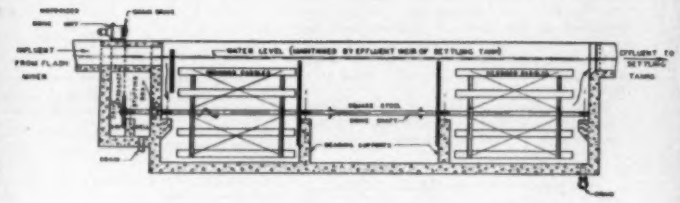

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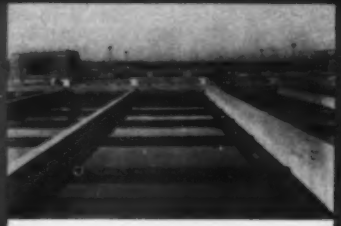

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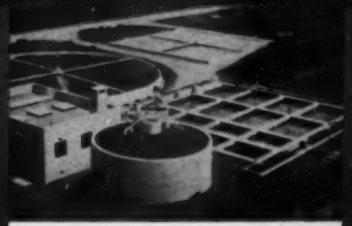

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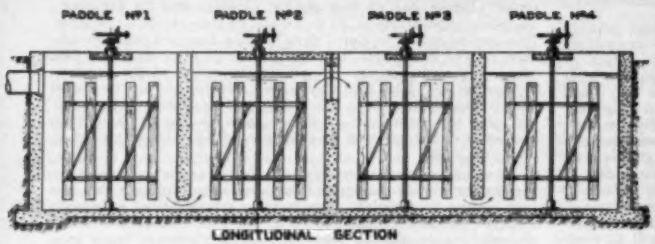

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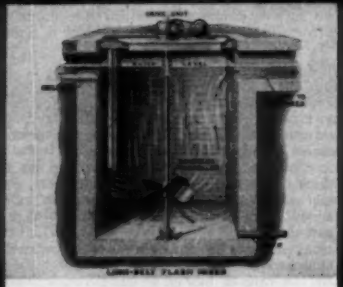

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OPERATING FUNDAMENTALS OF THE ACTIVATED SLUDGE PROCESS

T. R. HASELTINE,
Cons. Engr., The Chester Engrs., Pittsburgh, Pa.

THE properties of activated sludge which are most important to the plant operator are, first, its clarifying or absorptive powers, and, second, its oxidizing power.

When activated sludge is mixed with sewage it absorbs the finely divided suspended matter, the colloids, and probably much material in true solution in or on its floc surfaces. If the sludge is then allowed to settle out, the supernatant liquor will be clear instead of cloudy. This clarification action is very rapid and is probably completed in 10 to 30 minutes.

The oxidizing power of activated sludge is generally assumed to be entirely due to biological action. Although its oxidizing action may be some 60 to 130 times faster than the normal oxidizing rates, as measured by the standard B.O.D. test, it is still much slower than adsorption or clarification.[1] The highest rate of oxidation usually occurs when the sludge first comes in contact with the sewage. It then falls off gradually for the next two to five hours, after which it continues at a more or less uniform rate for considerable periods of time.

In any properly functioning plant there is a balance between these two properties. Almost all of the troubles encountered with the activated sludge process may be traced to a lack of proper balance. For example, if biological oxidation proceeds more rapidly than adsorption, the sludge floc become very small and compact. This dense floc does not produce a sparkling clear effluent although nitrification may be very high. Furthermore, some of the floc is apparently broken up into minute particles which do not settle in the final clarifiers, even though the main body of the sludge settles very rapidly. On the other hand, if oxidation lags behind adsorption, the sludge floc will become so light that it will not settle in the final tanks and the sludge will lose much of its clarifying power. Since adsorption is very rapid and almost automatic, the operator's problem is to regulate the rate of biological oxidation so that it just keeps pace with adsorption under the aeration periods prevailing in his particular plant.

There are several conditions under which oxidation will progress more rapidly than adsorption. Probably the most common is over aeration. It is encountered in plants having excessive blower capacity in a few large constant speed machines. It is best overcome by carrying more sludge in the aeration tanks. A second, but less common, cause of over oxidation is too long an aeration period. The best corrective is to bypass part of the aeration tanks. If that cannot be done, then increase the amount of sludge in the mixed liquor. A third cause of over oxidation may be lack of sufficient "food" in the sewage. The writer encountered such a condition at Grove City during the early spring. At such times our sewage flow is increased by ground water to four or five times its dry weather volume. Most of the excess flow has to be bypassed and hence only one-third to one-fourth as much organic matter enters the aerators as normally. We have found that the admittance (after liming) of digester supernatant to the aerators was quite helpful at that season.

Causes of Oxidation Lag

There are at least six possible causes of oxidation lagging behind adsorption, as follows:

(1) *Inadequate Oxygen Supply:* In any aeration tank (mechanical or diffused air) we have two opposing forces, one, the aerator device injecting air into the mixed liquor, and two, the biological organisms using up oxygen in their life processes. Dissolved oxygen determinations on the mixed liquor give a measure of the excess of the oxygen supply over the oxygen consumption. It is absolutely essential that the rate of supply be at least equal to the rate of consumption, but there is nothing to indicate that any great excess is beneficial.[2] If there is no dissolved oxygen in parts of the aeration tanks then either the oxygen supply must be increased by using more air, or the rate of oxygen consumption must be cut down by reducing the amount of sludge or sewage in the mixed liquor. Naturally sludge reduction is the most general practice.

(2) *Germicidal Wastes:* Since oxidation is entirely biological it is evident that germicidal wastes will stop or retard it. If the germicidal action is due to excessive acidity or alkalinity neutralization with lime or acid will eliminate it. (The optimum pH for biological oxidation is 7.0 to 7.5 although there is little retardation at pH 6.4 to 8.0.[4] If it is due to phenolic compounds or other toxic substances, the only certain remedy is to exclude them from the sewers. In some cases, however, where the concentration of the poison is quite uniform and not too high it may be possible for the sludge organisms to become accustomed to it.

(3) *Excessive Carbon Dioxide:* Carbon dioxide is one of the principal end products of biological oxidation[3,4] and excessive amounts of it are known to be toxic to bacterial activity. Sewage already contains relatively large amounts of CO_2. Although aeration is an efficient means of removing carbon dioxide the rate of its production during the activated sludge process is so great that the net reduction due to aeration may be slight. In such cases it is quite possible that the rate of oxidation is limited by the CO_2 content of the mixed liquor. When such conditions prevail it is logical to apply lime to the inlets of the aeration tanks.[4] Either one of two general schemes may be followed: (a) daily applications of 50 to 300 lbs. of lime per M.G. of daily flow applied in one to four "shots" during hours of peak sewage flow, or (b) continuous lime applications at rates of 300 to 500 ppm. until such time as the pH at the outlet of the aerators approaches 8.0. The best way to tell whether or not excessive CO_2 is causing trouble is to try the lime treatment. It is fortunate that this treatment can do no harm so long as the pH at the outlet of the aerators does not exceed 8.8, whether or not it does any good.

(4) *Septic Sewage or Sludge:* Septic action not only increases the carbon dioxide but produces other products that retard biological oxidation. Avoid sludge accumulations in sewers, channels, primary or final clarifiers. The return of large volumes of poor quality digester overflow liquor to primary tanks may cause the entire sewage flow to become septic. Frequent sewer flushing may be helpful. Prechlorination at various points along the collection system may be even more helpful. Partial chlorination of the return activated sludge has proved beneficial at some plants but chlorine is a powerful germicide and particular care is required to avoid over-chlorination of the sludge which might destroy its oxidizing power.

(5) *Excessive Grease Content of the Sludge:* If the grease content of the sludge is excessive the sludge particles become coated with a film of grease thus preventing intimate contact with oxygen, even though tests show an abundance of dissolved oxygen in the mixed liquor, hence oxidation is greatly retarded. Wiest's[5] work indicates that the activated sludge process functions satisfactorily when the grease content of the sludge is 5 to 7 per cent, but gives considerable trouble when the grease content is around 20 per cent. The writer's experience indicates that 13 per cent grease in the sludge makes for difficult operation while 30 per cent grease causes the sludge to lose its clarifying power and a very inferior effluent results. If the grease content of the sludge is generally excessive then some means of further removing grease from the incoming sewage is indicated. But where the trouble is caused only by periodic shots of mineral oil the writer has found a 25 per cent increase in air for a day following such shots to be helpful.

(6) *Inadequate Aeration Period:* Even under ideal conditions biological oxidation is much slower than adsorption and, hence, there is some minimum aeration period required below which the process will not function. Usually there is nothing the operator can do but bypass part of the sewage flow and ask for more aeration tanks. In some cases, however, short circuiting in diffused air plants has been a factor that could be corrected by proper baffling. Current meter readings at various points may be helpful in designing or locating baffles. In other cases it has been possible to delay major extensions by utilizing part of the aeration tanks for sludge reaeration, thus lengthening the available time for biological oxidation.

Since both the quantity and strength of the sewage varies from hour to hour and day to day, it might be asked, how is the operator to maintain a constant balance between adsorption and oxidation at all times? He can not! In the normal plant oxidation probably falls behind adsorption during the high flow of strong daytime sewage and catches up during the low flow of

weaker night sewage. In some plants it is even possible to observe a gradual deterioration of the sludge through the week with recovery over Sundays. It must always be kept in mind that it is only prolonged periods of excessive adsorption that cause serious sludge deterioration, and that several days of excessive oxidation are required for its recovery. The closer the balance is maintained the lower will be the power costs, but the higher will be the laboratory and attendance costs. Therefore more laboratory work is justified in large plants than in small, but some is required in all.

Sewage Input vs. Air Input, and the D. O. Test

Since most if not all of the oxidation occurs in, or on, the sludge floc, it should be evident that most of the oxygen is consumed by the sludge. Therefore, it is a serious mistake to attempt to regulate the air input in proportion to the sewage flow. Dissolved oxygen determinations throughout the aeration tanks are the best criterion known for air regulation. If the air is to be varied throughout the day then these tests should be made at various hours throughout the day. If a constant rate of aeration is to be used then the tests should be made at whatever time the dissolved oxygen is at a minimum; this will usually be found a few hours *after* receipt of the peak sewage flow. Samples should be collected from various points between the inlet and the outlet of the aerators. Unfortunately the dissolved oxygen determination, the most important of all operating control tests, can not be made directly on the mixed liquor because of interference from the sludge floc. The accurate determination is extremely difficult and requires special equipment,[7] however tests for routine plant control may be made on samples of supernatant liquor siphoned off from larger samples of mixed liquor collected from the aerators. At Salinas, California,[4] the writer collected 2 liter samples from the tanks and allowed them to stand until sufficient clear water could be siphoned off to fill the small D.O. bottles. Ordinarily 5 to 15 minutes standing sufficed although at times of severe bulking as much as 40 minutes was required. That procedure is open to the objection that the sludge consumes some oxygen during the sedimentation period. However, on several occasions we siphoned off a second sample an hour or two after taking the first one and repeated the D.O. determinations; the decrease in dissolved oxygen in the supernatant over the elapsed time was surprisingly small. Theroux, Eldridge and Mallman[8] recommended the addition of 10 ml. of 10 per cent copper sulphate solution to the 2 liter samples of mixed liquor. The copper sulfate acts as a coagulant, speeding up sedimentation, and at the same time halts biological oxygen consumption. Theoretically, at least, this method is open to the objection that the copper sulfate tends to react with the potassium iodide added later liberating iodine and thus giving results that are too high. Heukelekian uses about half as much 10 per cent sulfuric acid in place of the copper sulfate. The writer has tried all three methods simultaneously at Grove City on several occasions and found little or no practical difference. We use copper sulfate in our routine work.

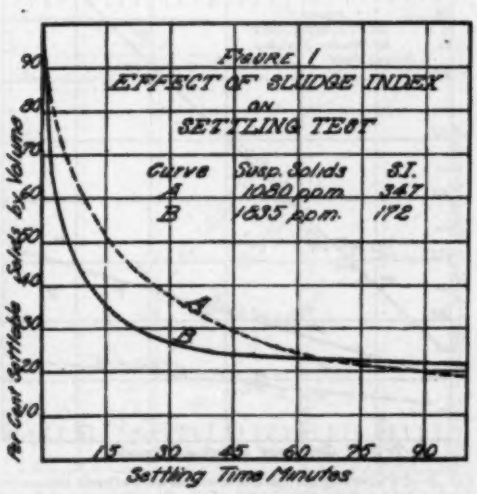

Fig. 1—The Effect of Sludge Density (Sludge Index) on the Volumetric Sludge Settling Test.

Regardless of the method used to separate out the sludge floc the Rideal-Stewart modification of the Winkler method should always be used for determining the oxygen in the small, siphoned samples because of the possible presence of nitrites in the liquor, see "Standard Methods."[20]

Measuring Sludge in Mixed Liquor

We have mentioned increasing or decreasing the amount of sludge in the aerators as a means of controlling the oxydation-adsorption balance. This leads us to the second most important control test, namely, some means of measuring the amount of sludge in the mixed liquor. By amount of sludge we mean *weight* of sludge solids. No universal rule can be given for determining the proper amount. Perhaps 600 to 1500 ppm. of suspended solids in the mixed liquor would cover most mechanical aerators while 1200 to 3000 would cover most compressed air plants. The higher the sludge content of the mixed liquor the faster will adsorption and oxidation progress, but the greater will be the power requirements. If the aeration period is short an increased sludge content will give a higher degree of treatment, but if an adequate aeration period is available almost as good purification can be obtained with a low sludge content and a considerable saving in power may be realized. With a low sludge content organic matter adsorption per unit weight of sludge is very high and hence a very high rate of biological oxidation must be maintained. Therefore, if the sludge content is low, there is more danger of a plant being upset by sudden shots of strong sewage or organic trade wastes.

Standard suspended solids determinations are the only accurate means of finding the actual weight of sludge solids in the mixed liquor. Unfortunately the test requires considerable time and, for small plants, expensive equipment. In spite of these handicaps the test is extremely valuable and should be made at least once a day at all but the very smallest plants. It should be made at the same time each day. The time selected should be such that the sewage flow for the past several hours has been nearly identical with that of the same hours of each preceding day—usually 8 or 9 a.m. will be the most satisfactory time. The writer has followed this practice at Salinas,[4] Topeka[10] and Grove City. We governed the daily amount of activated sludge, wasted almost entirely by the results of these determinations. This procedure does *not* accomplish the very desirable end of keeping the suspended solid content of the aerators constant at all times throughout the day. It was probably a minimum at the time the peak flow started coming in and at a maximum in the evening when the sewage flow drops off. However, it did serve to keep the *average daily* suspended solid content of the aerators fairly constant. If it is desired to hold the solid content of the aerators constant throughout the day then one of the approximate "short-cut" methods of solid determination (to be described later) may be used as frequently as desired, but the standard suspended solids test should be made daily as a check on the short-cut procedure. After considerable experimentation the writer has concluded that the saving in power made possible by hourly checks of the solid content of the aerators was not sufficient to justify the time consumed in checking, but such a conclusion can apply only to the plants with which he was connected. Anderson, employing a centrifugal estimation, has found the opposite to be the case at Rockville Center.[21, 24, 25]

Before leaving the subject of gravimetric solids determinations the writer wishes to make a plea for all operators to base their control on *suspended* solids determinations rather than on *total* solids determinations. It is the suspended solids in the sludge that exert the bulk of its oxygen demand. It would be permissible to base plant control on total solids determinations only if the dissolved solids were practically constant. Such is not the case—at Salinas[4] dissolved solids in the mixed liquor, and plant effluent, ranged from 600 to 1500 ppm. under varying sludge conditions; at Grove City the range is 200 to 500 ppm.

Because of the time required for suspended solids determinations various short-cuts have been used. The simplest are the settling tests and these were the earliest tests used. Samples of sludge or mixed liquor are simply collected in liter graduates, allowed to stand for some given time, and the per cent of settleable solids observed at the end of that time. In the early days it was usually customary to carry a volume of about 20 per cent sludge, after 30 minute standing of the mixed liquor. The test is still used and is quite helpful so long as its limitations are

kept in mind. Various standing times are used, ranging from 10 minutes to 1 hour or even longer.

The Sludge Index

Attempts to correlate the volume of settleable solids, as determined in this way, with the actual weight of suspended solids in the sample soon showed that no such relationship existed unless the sludge index[8] was also taken into consideration, see Figure 2. "The sludge index (S.I.) is the volume in cubic centimeters occupied by 1 gram of sludge solids after settling 30 minutes"; it is computed by multiplying the per cent sludge by volume after 30 minutes standing by 10,000 and dividing that product by the parts per million of suspended solids by weight in the same or a similar sample of mixed liquor. The longer the settling test samples are allowed to stand, i.e., the more the sludge compacts, the less the influence of the S.I. on the results of the test and, hence, the closer their approximation to the actual weight of sludge solids present. Figure 1 illustrates this point fairly well. In general the settling test alone cannot be relied on except in the smallest plants, and even then only in those small plants that are so amply designed that they are subject to little bulking. In such plants the possible saving in power may not be great enough to warrant the added cost of conducting more accurate determinations.

The Centrifuge Test

Another short-cut is the centrifugal test. This test consists of collecting samples of mixed liquor or sludge in 15 ml. centrifuge tubes and "spinning" them for a given short time (2 to 10 minutes) in an electrical centrifuge. A hand centrifuge will not serve because of the impossibility of always spinning the samples at the same speed.

The writer first heard of this test being used at the Indianapolis plant in 1928. Like the settling test, it is, at best, a volumetric determination. Nevertheless, it has two outstanding advantages over the gravity settling test. First, it is extremely rapid, and, second, it compacts the solids more and hence there is better correlation between its results and those of gravimetric suspended solids determinations. The writer has used a 2 minutes spinning period at 2600 r.p.m. at Salinas and Grove City. At both plants we found that the results of this test were greatly influenced by the sludge index, see Figure 3. Setter[10] used a 10 minute period at the same speed and got fair correlation with the suspended solids test so long as the suspended solids exceeded 1000 ppm.; at lower solids concentrations the volume of sediment was too small to permit satisfactory readings. Anderson[11, 12, 13] used a 5 minute period at 1800 r.p.m. at Rockville Center and considers the test very satisfactory although he gives no data to correlate it with suspended solids determinations. If the test is to be used the operator should first make sufficient trials to prepare a graph similar to Figure 3. Once such a graph is available he may determine the sludge index at daily to weekly periods and from that determination and the graph he can select the desirable centrifugal test results for more frequent determinations.

In addition to determining the amount of sludge being carried in the aerators it is desirable to know something of its condition. The sludge index, as previously described, is valuable in this respect. Color, odor, and floc structure are also valuable. Periodic microscopical examinations are useful. After a little experience these tests, or observations, will usually be found adequate for most plants. In some cases the volatile content or dissolved solids content of the sludge may be found helpful.[8] Still better tests required special equipment such as the Odeeometer,[14] Oxy-Utiometer,[15] etc.

Tapered Aeration vs. Delayed Loadings

It was previously stated that the rate of oxidation was usually highest when the sludge first comes in contact with the sewage and that afterwards it falls off gradually. If the air is supplied in just sufficient amounts to maintain a minimum dissolved oxygen content at all points in the tanks it will be found that considerably more air is used at their inlet ends than is used at their outlets. This method is known as *tapered aeration*. Since the rates of adsorption and oxidation increase with increased amounts of sludge, tapered aeration is more necessary when a high sludge content is carried. The rate of oxygenation is limited for any aeration device, but is generally lower for mechanical aerators than for compressed air plants,[7] hence the former usually carry less sludge and frequently provide longer aeration periods. At the Tallman's Island[16] plant provision is made for adding sewage or return sludge at several different points along the aeration tanks, thereby avoiding the necessity of using such high aeration rates at their inlets. In small plants it is possible to reduce the necessity for tapered aeration by returning a large volume of very dilute sludge. Experience has taught many operators that this practice is a good one for small plants in particular. The excess water reduces the oxygen demand of the mixed liquor at the aerator inlets and forces the sludge along the aeration tanks faster, thereby reducing the air requirements at the inlet end and increasing it further along the tanks.

Importance of Prompt Sludge Recirculation

It used to be considered good practice to carry a considerable depth of sludge in the final clarifiers in order to get as high a solid content, and hence as low a volume of return sludge as possible. Studies[17] have shown that the oxygen demand of such sludge is frequently so high that it is almost impossible to satisfy it by any aerating device. It has also been found[18] that the activity of the sludge was greatly impaired by even comparatively short concentration periods in the clarifiers and that the fresher the sludge the greater was its purifying power; the effect being most noticeable at plants having a short aeration period. Therefore, the rate of withdrawal from final tanks should be such as to remove the sludge as quickly as possible. In large plants where the cost of pumping excess water may exceed attendance, or in plants using sludge reaeration, it is wise to make frequent sludge soundings and to keep the rate of withdrawal at a minimum consistent with rapid sludge removal. In small plants that do not have sludge reaeration this extra attendance is not justified and a very high, constant, rate of sludge withdrawal can be used throughout the 24 hours. When the plant is treating a strong sewage the daily sludge withdrawal may be actually equal to the sewage flow with no ill results and, possibly, some benefit. (At first it might appear that such an increase in volume of sludge return would unduly shorten the aeration period; however, it may be shown mathematically that increasing the rate of return from 20 per cent to 50 per cent (equal sludge and sewage volume) cuts the nominal aeration period only 10 per cent because so much of the liquor in consequence passes through the aerators more than once.)

Most plants are not designed for sludge reaeration. If reaeration is used it is desirable to keep the rate of sludge withdrawal from the final tanks at a minimum, consistent with rapid sludge removal, in order to have the longest reaeration period, *providing it is possible to maintain some dissolved oxygen at all points in the reaeration tank.* If that can not be done then the rate of withdrawal *must* be increased so as to reduce the oxygen demand of the reaerating sludge.

Sludge Concentration Important

To intelligently divide the sludge withdrawal between return and waste it is necessary to make daily suspended solids tests on the mixed liquor, as previously discussed. If these results are

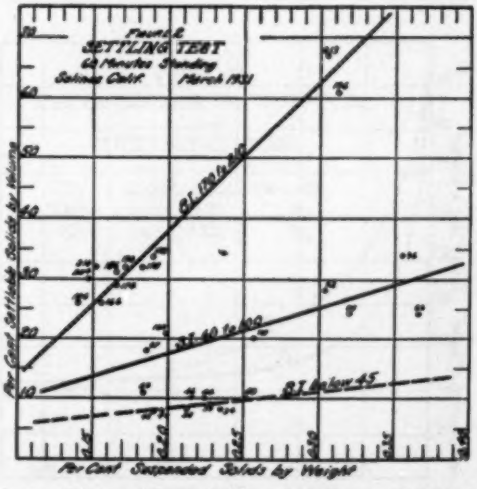

Fig. 2—A Picture of the Lack of Correlation Between Volumetric Sludge Test and the Gravimetric Test. The Necessity of Taking into Consideration the Density and Settleability (Sludge Index) Is Clearly Evident.

below the amount of sludge desired the amount going to waste should be decreased and vice-versa. Waste activated sludge should always be concentrated before introducing it into sludge digestion tanks. At most plants the only means of concentration provided is the introduction of waste activated sludge into the primary settlers. It has been the writer's experience that where this method is used better concentrations of primary sludge are obtained by wasting continuously over the 24 hours at a low rate than are obtained by wasting at a high rate for a shorter time. This method of wasting excess activated sludge has many disadvantages,[21] particularly when the sludge is bulked. A better, though less common method entails the use of a separate tank, termed a sludge thickener, and the use of chlorine.[14, 22] Where a thickener is provided best results are obtained by feeding it with mixed liquor direct from the aeration tanks instead of with sludge withdrawn from the final clarifiers. The clear, chlorinated supernatant from the thickener may be discharged to the incoming raw sewage, the return activated sludge or the final effluent. Either of the first two are preferable because of its beneficial action in overcoming septicity.

Troubles

Now just a few words concerning troubles. Sludge bulking is probably the most common trouble encountered with the activated sludge process. The term "bulking" has been used by some to cover the condition of sludge pouring over the weirs of final clarifiers, but the writer considers that an improper use of the term. A bulked sludge is simply a sludge that, after a given settling period, occupies a greater volume than would a normal sludge containing the same amount of suspended matter by weight. Bulking is best measured by the sludge index[3] as previously described. Whether or not a bulked sludge will pour over the weirs of final clarifiers depends, primarily, upon the design of those tanks. The more generous their design the higher can the sludge index become before the effluent is fouled.

It was previously stated that when oxidation lagged behind adsorption the sludge floc became so light that it would not settle properly, in other words, the sludge bulks. We have given six possible causes of oxidation lagging behind adsorption and suggested means of overcoming them. Any one of those six will cause bulking if not corrected. Certain microscopic, filamentous, growths will cause, or increase, bulking. Sphaerotilus is far the most common organism. Even though the sludge is constantly seeded with these organisms they do not flourish in the sludge if oxidation is keeping pace with adsorption, but if oxidation lags behind adsorption the sludge may become an ideal habitat for profuse growths. Correct the oxidation-adsorption balance and the number of Sphaerotilus will greatly diminish. Other filaments than Sphaerotilus may cause bulking, notably Cladothrix and Leptothrix, but their occurrence is so rare as to warrant no discussion here.

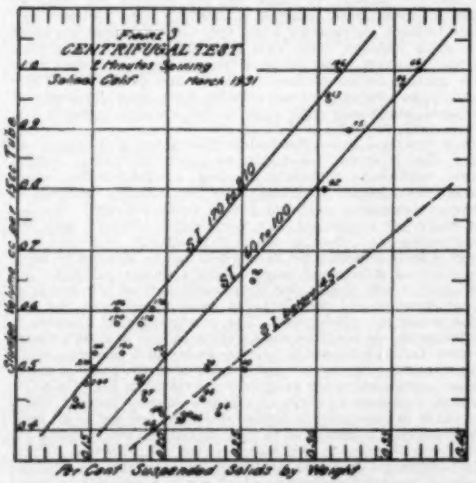

Fig. 3—A Picture of the Less but Evident Effect of Sludge Index Values on Suspended Solids Tests With the Centrifuge.

Bulking is not the only cause of excessive amounts of sludge passing out with the final effluent, although it is the most common one. There are two other causes. One is simply insufficient sludge withdrawal, the other is "sludge rising." Rising sludge is most commonly encountered in plants treating sewage high in nitrogenous matter (notably meat packing wastes) where nitrification is quite high. The sludge will settle rapidly in tanks or graduates, but will rise again in from 20 to 90 minutes. The sludge is lifted by accumulations of nitrogen gas. At some plants[24] it has been overcome by keeping the dissolved oxygen in the aerators very low; at others[25] it has been found helpful to increase the amount of sludge carried in the aerators.

Digester overflow liquor has caused considerable trouble at several activated sludge plants, among them Grove City. At most plants it is common practice to return digester overflow to the raw sewage, and, in a properly proportioned plant, the liquor will cause little or no difficulty providing its solid content does not exceed 0.2 per cent. If the overflow contains more than 0.5 per cent solids it turns primary clarifiers septic and covers them with gas-buoyed sludge. Under such conditions their effluent is very difficult to treat by the activated sludge process. At Grove City we have an overflow averaging well over 1.0 per cent solids. We add lime to it and turn it directly into the aeration tanks. The proper lime dosage, in our case, seems to be about 1 pound of lime to each 10 cubic feet of liquor. The liquor turns the aerators very dark, detracts from the appearance of the effluent, and unquestionably puts a tremendous burden upon the activated sludge process. However, we have been able to treat most of the liquor in this way although it seriously upset the plant when we attempted to return it to the raw sewage.

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SEWAGE SLUDGE AS A FERTILIZER*†

By A. H. NILES

Superintendent, Division of Sewage Disposal, Toledo, Ohio

NEW operators of sewage plants have often been amazed at the lush growth of garden produce which springs up as volunteer plants around sewage works, many times growing in the partially dried sludge cake undiluted with soil. This observation probably occurred most frequently with tomato plants, which as they grew were much sturdier, much deeper green and much larger than those which happened to grow in the surrounding soil unaffected by sewage sludge.

This new operator probably had only a passing interest in the appearance of these plants but as the season progressed and the fruit began to ripen, the day came when he was perhaps short of sandwiches or was long on appetite. The appearance of a particularly large and luscious looking tomato became irresistible. He had become sufficiently well acclimated to the atmosphere of a sewage treatment works to overcome his natural aversion to the thought of eating a fruit or vegetable which was fertilized directly by human feces, whether fully digested or not.

As this new operator sampled the appealing fruit, he smacked his lips and probably murmured "Hmm—not bad." From that time on he was sold, and being more or less a loquacious individual, did not wish to hide his discovery "under a bushel." He told his friends and they in turn told theirs so the story of sludge as a fertilizer began to be a matter of not uncommon knowledge. However, as in most cases of this kind, there was considerable misinformation disseminated along with the truth. Soon extravagant claims were made that sewage sludge was the universal panacea for all the ills of the agricultural world. Unscrupulous promoters claimed that sewage plants could be made self-supporting solely by the sale of their sludge as fertilizer.

Farmers long had believed that the only difference between the commercial fertilizer manufacturer and Jesse James was that the commercial product gave no visible evidence of the company having horses, and the salesmen usually did not wear spurs. Soon the commercial fertilizer companies were worried to the point where they were putting out their own brand of propaganda. These statements were that sewage sludge was of such low value that it was not worth hauling home or spreading on the fields even if given to them. Also, that it was full of disease producing bacteria and the user of the produce would certainly contract horrible afflictions or death. As is almost universally the case, the truth, probably, lay somewhere between these two widely divergent viewpoints.

Early Work at Toledo

The writer, being of Welsh extraction, which according to some, is a Scotchman raised to the *n*th power, felt that it was economically wrong to throw away anything of demonstrated value. When the Toledo sewage treatment plant was started, it was decided to give the sludge away for a limited time for advertising purposes. This was all right except for the fact that a few persons obtained sludge which was insufficiently dried. When this was spread upon their lawns and their small children ran across the yard and tracked the sticky mess into the house, their irate mothers promptly consigned the sludge and all persons connected therewith to the place where sludge drying could be most economically accomplished. These unfortunate incidents, together with the psychological fact that, to many persons, anything obtained "for free" has no value, gave the sewage sludge program something of a setback before it really got under way.

A start was made, however, with an attrition mill borrowed from a miller friend. It was not well suited for the purpose but did a passably good job. This was followed by a threshing machine concave and that in turn by a light farm hammer mill primarily suited for grinding grain and feed. Quite a lot of tonnage was put through that old farm mill and the product packaged in used calcium chloride burlap bags obtained from the Street Division. This package was an unattractive one and, besides, its printing indicated that it contained a product to lay dust or melt ice instead of to grow plants. It was sold to the relatively few persons who had previously used the free sludge and were sufficiently pleased with the results to part with real money. This was especially noteworthy because it occurred at a time when pocketbooks were flat—when the CWA leaf-raking program was at its height and national budgets were ending with six zeros instead of nine.

Finally, in 1937, a WPA project was approved to construct a plant to prepare economically the dried sludge for fertilizer and a warehouse to store it in. A contest was initiated in June, 1938, to name the child formally. Many names submitted were not thought usable because of being too expressive, but as a final result, the infant was christened "Tol-e-Gro." Its godfather was rewarded by a handsome prize of 10 bags of the material—a part of which he promptly gave away to his close friends and neighbors.

A multiwall paper bag, printed in two colors, with analyses and complete instructions for use was adopted together with modern equipment for preparing, bagging and handling. A modest newspaper advertising program was inaugurated and a salesman hired for two seasons to get the merchandising campaign under way. Most of this took place in 1938 and 1939. Since that time the only advertising done has been the printing of folders used by dealers to acquaint their customers with Tol-e-Gro. No salesman has been needed since 1939, for every bit of Tol-e-Gro that could be dried has been sold. In the spring of 1943 at least 250 tons more could have been sold if it had been available.

Just about this time, in the Fall of 1937, the Toledo plant had the good fortune to obtain a chemist who had the background, the training, the energy and the inquisitive mind to do a good job of research. His assignment was to find out what made sewage sludge "tick." It is the purpose of this paper to tell you some of the things he found out.

Fertility Factors in Sludge

First of all, from general observation, it was assumed that sewage sludge had something that promoted growth other than the amounts of nitrogen, phosphoric acid and potash that could be determined from analyses in the chemical laboratory. All that is necessary to confirm this observation is to read the history of China. The Chinese have used their waste products—human, animal and vegetable—for centuries as fertilizers. Their lands are still among the most fertile in the world. Chemical fertilizers were unknown to these uninformed people, yet they maintained the fertility of their land. Their country was too crowded to move to more fertile, virgin fields. It was absolutely essential that they maintain their soil fertility. To do so they used the above mentioned wastes, putting them back into the soil. In Europe, the farmers of today will not tolerate the waste of manures—even human manure is carefully used for fertilizer. These farmers, undoubtedly, knew very little and cared less about how much nitrogen, phosphoric acid and potash were in their wastes. However, they did know that these wastes were what their ground needed to keep it fertile and productive. These manures and natural wastes actually were poor fertilizers if compared analytically with some of the so-called complete fertilizers, such as 4-12-4 or 5-10-10, etc.

It is true that these chemical fertilizers are giving good results. But is it not reasonable to believe that these natural wastes must have something in them or their action which makes them better fertilizers than the straight analysis of nitrogen, phosphoric acid and potash would indicate? No one can make up a standard mix commercial fertilizer with the same analysis as Tol-e-Gro, which is 2.0-2.0-0.30, and come anywhere near to obtaining the results that can be obtained by using Tol-e-Gro or a barnyard manure with a similar analysis. Immediately, it will be said that the organic form of nitrogen is of longer duration and the plant fed more continuously, but that again is not the whole story. The purely chemical analyses in the laboratory do not show the countless billions of little nitrogen fixation factories found in sewage sludge and manures which take nitrogen from the air and convert it to the form of nitrogenous compounds easily assimilable by the plant life. Tol-e-Gro contains enormous numbers of nitrogen fixation bacteria which are found in some soils in limited quantities but not in all soils. Their presence is conducive to good fertility. These bacteria are collectively known as Azotobacters and Nitrobacters. These micro-organisms have the power of transforming the nitrogen in the air to useful compounds which can be assimilated by plants for food. They not only make nitrogen more available to plant life but they also attack and break down humus, straw, old dead roots and other organic substances in the soil, to useful, life-giving stimulating compounds used by the plant life.

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†Ed. Note: Although this article was prepared about and mentions Tol-e-Gro, the sludge from Toledo, Ohio, the information herein is undoubtedly applicable to digested sludge from other sewage plants.

Nitrogen and Nitrate Content

It was found that Tol-e-Gro will increase its nitrogen content by 20 per cent in 7 days if moistened and allowed to stand exposed to air. This nitrogen in the air is changed to ammonia and nitrates which are eagerly taken up by the plants and utilized in their normal metabolism. The Texas Experimental Station Bulletin No. 445 states that similar sewage sludge mixed with samples of different kinds of soils produced from 64 to 134 parts per million of nitrate nitrogen. This is more nitrate nitrogen than is produced in some higher analysis fertilizers. This variation is due largely to the variations of soils rather than to the sewage sludge itself.

Since a medium or normal nitrate soil will show 5 to 15 parts per million, according to Michigan Technical Bulletin No. 132, it is obvious that sewage sludge gives an abundant supply of nitrate nitrogen. Quoting from the above Bulletin No. 132, "The nitrogen of the soil organic matter is transformed to ammonia and then to nitrites and finally to nitrates by means of the action of soil organisms. This process is known as nitrification. In order for a soil to form nitrates naturally, it should have a supply of nitrogen in organic matter, be moist, warm and aerated and have the nitrifying organisms present. Soils low in organic matter are usually low in nitrate and nitrifying organisms. Growing plants obtain most of their nitrogen from the soil as nitrates." Nitrates are water soluble and, unless protected by organic matter, are easily washed through the soil.

Tol-e-Gro supplies an abundance of these nitrifying organisms as well as a good reserve supply of organic matter and prevents leaching of valuable nitrate salts from the soil. The amount of ammonia in the soil is dependent upon the same factors as nitrates, that is, abundance of organic matter and nitrifying organisms. Chemical salts used on soils are easily leached out by heavy rains and partly wasted as far as soil nutrition is concerned.

The use of sewage sludge or manure will, in a large measure, control this leaching as it will hold many times its volume and weight of moisture, thus keeping the dissolved nutrients in contact with roots for a much longer time than would otherwise be possible.

Most sewage sludges have a residual or reserve property of releasing food as the plant needs it. These organisms will make just a certain amount of excess ammonia or nitrate which is more than the plant needs. They cease production of these nutrients and cease their activity until the nitrate concentration falls somewhat. Then the nitrifying bacteria start making more ammonia and nitrate from the air. Thus, there is always available an ample supply of usable nitrogen.

Sewage sludges and manures are helpful in making heavy clay soils porous and workable. Sandy soils are helped by the humus present in sewage sludge and by the moisture-holding properties of the sludge. Sandy soils are almost always deficient in nitrifying bacteria and certain colloidal conditions which are essential to plant growth. Tol-e-Gro supplies the soil with microorganisms and helps correct these colloidal deficiencies.

Chemical Constituents

Many elements are essential to plant growth other than nitrogen, phosphorus and potassium. Many crops have been thoroughly analyzed to find just what elements are needed in their growth. Analyses were made of corn, wheat, sugar beets, alfalfa, tomatoes, barley, rye and cabbage, as reported in *New Agriculture*, April, 1937. The following elements were found to be present in the above crops: nitrogen, phosphorus, potassium, calcium, aluminum, arsenic, barium, beryllium, boron, bromine, chlorine, chromium, cobalt, copper, fluorine, iodine, iron, lead, lithium, magnesium, manganese, molybdenum, nickel, rubidium, silicon, silver, sodium, strontium, sulfur, tin, titanium, vanadium and zinc. This totals 33 elements in all. Of these elements, 22 are present in corn, 26 in wheat, 20 in sugar beets, 27 in alfalfa, 22 in tomatoes, 14 in barley, 15 in rye and 22 in cabbage. Therefore it seems reasonable to assume that a good fertilizer should include more than just nitrogen, phosphate and potash. Tol-e-Gro shows the presence of 29 of these various elements.

Sewage sludge has an abundance of mineral elements, many of which are present in such forms as to be slowly and sufficiently available to plant life. Since about 30 different minerals are being constantly taken from the soil by crops, it seems reasonable that replacement of many of these elements is advisable.

A composite sample of 325 tons of Tol-e-Gro was carefully collected and analyses made of same sample. These analyses are quite complete for all common mineral and non-metallic constituents, and the results, shown in the accompanying table, are expressed in pounds per ton of Tol-e-Gro:

Chemical Constituents of Tol-e-Gro.

Constituent	Pounds per ton	Constituent	Pounds per ton
Aluminum	72.0	Lithium	Tr.
Arsenic	.2	Magnesium	22.0
Barium	1.0	Magnesia equivalent	36.5
Bismuth	12.0	Molybdenum	Tr.**
Boron	+*	Nickel	Tr.**
Bromine	Tr.**	Nitrogen	42.4
Calcium	94.8	Organic Matter	888.0
Ca as limestone	236.8	Potassium	7.0
Chlorine	+*	Phosphoric Acid	40.3
Chromium	5.0	Selenium	Tr.**
Cobalt	Tr.**	Silicon	146.0
Copper	16.0	Sodium	+*
Fluorine	+*	Sulfur	63.0
Iodine	Tr.**	Tin	Tr.**
Iron	76.0	Zinc	20.0
Lead	15.0		

*Undetermined amounts, but more than a trace.
**Spectrographic analysis confirmed these trace constituents.

It is fitting at this time to take up some of these various elements, showing in some measure just how and why they are vitally important in the metabolism and growth of plants.

Aluminum: Essential to plant growth. It is usually present in soils in sufficient quantity although it may be deficient in sandy soils. Along with the organic matter in the soil, aluminum is active in controlling the colloidal functions and water-conserving properties of the soil.

Arsenic: The following statement is taken from *New Agriculture*, April, 1937, issue: "Although formerly believed to be toxic in certain concentrations, it has proven beneficial and stimulates the growth when present in small quantities. As much as 1,000 lbs. per acre have not proven toxic in experimental work." Dr. J. E. Groves of Utah says "Arsenic stimulates bacterial action in the soil resulting in greater crop yield." He further states: "Arsenic must be applied in enormous amounts before it retards microscopic life." Experiments show that arsenic causes liberation of insoluble elements in the soil, especially phosphate.

Barium: Found in varying amounts in some plants. It is believed to prevent injury from excessive concentrations of other elements. However, there is not much known about the value of barium except that it is found in the structure of some plants, namely, corn, wheat, sugar beets, alfalfa, tomatoes and cabbage.

Boron: Much work has been done on the influence of boron on plant growth in the last 20 years. Warington (1923) and Breachley (1927), at the Rothamsted Experiment Station, believe that boron is essential to plant growth, and this belief is concurred in by Sommer and Lipman (1926), Johnson and Dove (1928) and others in this country. Collins (1927), working at the New Jersey Experimental Station, found that boron did have a stimulating effect when present in small quantities.

Calcium: One of the very essential elements. Non-legume crops will require at least 25 lbs. per acre, while legumes, alfalfa, clover, etc., will require 100 lbs. and more per acre. Most soils, it is true, have calcium in their make-up but it is not always in an easily available form. Calcium, more or less, controls the acid and alkaline balance in the soil. It has a controlling influence on the translocation of sugars and starches in the plant. It is essential to the construction of healthy cell wall of plant tissue.

Chlorine: Apparently useful to plants in small quantities. It seems to have a catalytic effect and tends to make other elements more available.

Copper: Found in many plants and it appears to be essential for sunflowers and tomatoes. Copper gives good results, especially on wet, boggy lands where most minerals have been leached out of the soil. Copper, along with manganese, has decidedly beneficial results with carrots, radishes, beets, cabbage and other garden crops.

Cobalt: In small quantities has been found to stimulate crops. It has been found to be important in tomato, wheat and corn culture (*New Agriculture*, April, 1937).

Magnesium: As essential to plants as phosphorus or potash, yet until recently experimental stations and fertilizer industries have paid little attention to the possibilities of a magnesium hunger or magnesium fertilization. Most plants will show from 5 per cent to 10 per cent magnesium oxide in their ash. Magnesium is a constituent of the chlorophyll molecule. It is absolutely necessary in the production of a healthy green color in plants. Magnesium plays an important role in the translocation of starches in the plant. It is an essential factor in the formation of vegetable fats and oils and functions as a carrier of phosphorus in plant metabolism. Bartholomew (1933) has gained evidence showing that soluble magnesium in plants increases the absorption of phosphorus. Cooper (1930) found that magnesium is desirable for resinous plants. Sewage sludge carries large amounts of easily available magnesium. Loew (1901) showed that for the best development of most common field crops the soil should have a calcium-magnesium ratio of 2 parts of calcium

to 1 of magnesium. During wet seasons magnesium is easily leached from the soil. The combination of magnesium with organic material is, therefore, highly desirable as the organic material helps prevent excessive leaching.

Iron: Very essential but most soils contain sufficient amounts for normal growth.

Manganese: A constituent of nearly all field and garden crops. It is now considered to be one of the essential elements for normal growth. McHargue (1926) of the Kentucky Experimental Station demonstrated conclusively that manganese was essential for plant growth. Manganese appears to be necessary in the normal oxidation reactions taking place in plant metabolism. Addition or incorporation of manganese in fertilizers to be used on alkaline soils or soils underlain with lime is important as the alkalinity reduces the availability of manganese. Therefore alkaline soils are apt to be deficient in available manganese. Manganese deficiency is due, largely, to the increasing scarcity of manure. Manure usually contains sufficient manganese for most soils. Sewage sludge contains an abundange of manganese, even more than manures, and is a very good carrier of manganese for fertilizer use.

Sodium: Easily leached from soils and should be replaced. Beets, mangoes, potatoes, wheat, barley and asparagus respond quickly to the presence of sodium salts in the soils. Some experimental stations are using top dressings of sodium chloride, or common salt, with remarkable increases in crops. Sodium seems to help conserve the phosphorus and potash and help the normal reactions in the plant.

Sulfur: Proved to be an essential element to plant growth in 1860. Sulfur is a constituent of many plant proteins, cereals, etc. Sulfur is a constituent of plant flavors and aromatic oils and is a constituent of mustard oil, onions, garlic and many other flavors more pleasant. Many plants require more sulfur than phosphorus (*Commercial Fertilizers*, Collins, 1934).

The annual loss of sulfur through drainage is estimated at between 20 and 50 lbs. per acre. Many plants will respond remarkably to sulfur. Alfalfa will respond to sulfur even better than nitrogenous fertilizers. Cases of alfalfa increases with sulfur-carrying fertilizers have been reported from 50 to 500 per cent. Sulfur increases root growth in most plants (Crocker, 1933). Garden crops such as cabbage, lettuce, radishes, beans, peas, etc., respond readily to sulfur.

Tol-e-Gro contains sulfur bacteria which change insoluble forms of sulfur to soluble sulfates which are available to plants. Tol-e-Gro is rich in sulfur—65 lbs. per ton.

Small amounts of zinc seem to be important to plant life as zinc is found in almost all of the common crop plants and fruits. Zinc controls mottle leaf and rosette in fruit trees.

Other Benefits

Users and experimenters of sewage sludge as fertilizer have repeatedly called attention to the fact that results obtained by using Tol-e-Gro and some similar products are far better than the nitrogen, phosphoric acid and potash analysis would indicate. The importance of other mineral constituents has been shown in a small way. Taking all these minerals into consideration, the results obtained by using Tol-e-Gro are still beyond those expected from the straight, routine, standard analysis.

This may be partially explained on the basis of increased moisture-holding capacity; the change in soil structure, allowing more air to enter and subsequently stimulating oxidation; introduction of large numbers of bacteria to aid decomposition and better balancing of the nitrification processes and flora of the soil.

It has been found in running laboratory comparative tests that the plants grown with Tol-e-Gro had two or three times the root growth of plants grown under identical conditions with commercial 4-12-4 fertilizers. Also, comparative tests with potatoes grown on good loam soil resulted in a 200 per cent increase for hills fertilized with Tol-e-Gro at the rate of 400 lbs. per acre. The root growth was noticeably greater and the potatoes were larger. A search was started to determine in some measure the cause of these fine results and increased root growth. In recent years considerable attention has been focused on the fact that certain organic compounds or chemical substances are able to increase root growth and stem elongation and to influence changes in plant growth. It was in this direction that the search was started.

It is well known that in the presence of nitrifying bacteria, such as Azotobacter Chroococcum, something was formed which induced increased root growth. As previously stated, Tol-e-Gro is virtually alive with nitrifying bacteria. It has been shown that these growth promoting substances are probably not made by the bacteria but are produced as bacteria break down the organic materials upon which they feed. Tol-e-Gro is rich in these organic substances. This explained, in part, the origin of these chemical substances, but the next thing was to demonstrate their presence and approximate the amounts present. These substances were found to be present in small quantities when expressed as pounds per ton, but this is more than sufficient when compared to the requirements for plant stimulation. These substances were identified as derivatives of indole, a complex organic chemical.

Growth Promoting Substances

Dr. Willem Rudolfs, head of research of the New Jersey Agricultural Experiment Station, Dept. of Water and Sewage, together with Messrs. Heineman and Ingols, reported in *Sewage Works Journal*, Vols. 10 and 12, on various growth-promoting substances found in sewage sludge. Their conclusions were that most growth-promoting substances found in sewage sludge were from indole and skatole in the form of indole acetic, indole propionic and indole butyric acids. Tryptophane is also formed by digesting or decomposing sludge. Carotene and ascorbic acid are present in limited quantities.

Many of these substances are soluble and tend to wash or drain out of the digesting sludge. It was found that concentrated filtrate collected from the underdrainage system of the glass-covered sludge drying beds at Toledo was far more potent in growth-promoting substances than the dried sludge. This corroborated the statement heard many times that "the best part of sludge is drained away."

Damoose at Battle Creek, as did Backmeyer at Marion, Ind., found this to be the case when they advocated using, and actually sold on an applied basis, quite large amounts of liquid digested sludge. This method of use certainly has its limitations, but, where possible to handle it economically, it produces wonderful results. For years Hommon, at Canton, O., has disposed of liquid digested sludge directly to a city-owned farm adjacent to the sewage treatment plant, with phenomenal crop yields.

In conclusion, it may be summed up that, measured by purely chemical analyses, sewage sludges do not compare very favorably with many commercial fertilizers. Sewage sludge probably never will drive commercial fertilizer companies out of business. Many of these companies do use sewage sludge as a base and fortify it with additional chemicals to gain the analysis desired. This, in part, gains for the commercial fertilizers some of the advantages sewage sludges have.

Even the worst critics of sludge, however, unwillingly perhaps, admit that it has some properties that give plants an "oomph" that a standard commercial fertilizer just does not have.

CONTENTS OF HORIZONTAL TANKS AND PIPE

Per Foot of Length, for Various Depths

Formulas for determination of approximate capacity of horizontal cylindrical tanks for any depth. Given: Diameter of tank *d* and height of segment *h*.

To find area of segment.

when $h = 0$ to $\frac{1}{2}d$; area $= h\sqrt{1.766\,dh - h^2}$

when $h = \frac{1}{2}d$ to d; area $= h\sqrt{0.017d^2 + 1.7\,dh - h^2}$

1 cu. ft. = 7.4805 U. S. gal.

h = Depth of Liquid Inches	d = Diameter of Tank, Inches									
	12		18		24		30		36	
	Gal.	Cu. Ft.	Gal.	Cu. Ft.	Gal.	Cu. Ft.	Gal.	Cu. Ft.	Gal.	Cu. Ft.
2	0.64	0.0860	0.80	0.1072	0.93	0.1244	1.05	0.1400	1.15	0.154
4	1.73	0.2317	2.18	0.2920	2.57	0.3440	2.90	0.3878	3.21	0.429
6	2.94	0.3927	3.85	0.5149	4.59	0.6140	5.23	0.6988	5.80	0.775
8	4.14	0.5537	5.67	0.7578	6.85	0.9152	7.85	1.049	8.75	1.17
10	5.23	0.6994	7.55	1.009	9.26	1.238	10.72	1.432	12.0	1.60
12	5.87	0.7854	9.38	1.252	11.75	1.571	13.72	1.833	15.4	2.03
14	.....	.....	11.04	1.476	14.24	1.903	16.82	2.248	19.0	2.54
16	.....	.....	12.43	1.659	16.65	2.226	19.90	2.660	22.6	3.02
18	.....	.....	13.22	1.767	18.91	2.527	23.00	3.075	26.4	3.53
20	.....	.....	.....	.....	20.93	2.797	26.00	3.476	29.6	3.95
22	.....	.....	.....	.....	22.57	3.017	28.85	3.859	33.4	4.46
24	.....	.....	.....	.....	23.50	3.141e	31.49	4.209	37.4	5.00
26	.....	.....	.....	.....	.....	.....	33.82	4.521	40.4	5.40
28	.....	.....	.....	.....	.....	.....	35.67	4.768	43.7	5.84
30	.....	.....	.....	.....	.....	.....	36.72	4.908	46.6	6.23
32	.....	.....	.....	.....	.....	.....	.....	.....	49.1	6.55
34	.....	.....	.....	.....	.....	.....	.....	.....	51.2	6.85
36	.....	.....	.....	.....	.....	.....	.....	.....	52.9	7.07

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ADDITION OF GARBAGE TO SEWAGE

By T. R. HAZELTINE
The Chester Engineers, Pittsburgh, Pa.

THERE are four different ways by which garbage has been added to sewage. The oldest and most common method is the "lift the seat, dump and flush method," which has probably been in use ever since sewers and commodes were invented. That this method is extremely common is evident to anyone who examines the screenings or scum on a primary settling tank at almost any sewage treatment plant. The method is not scientific, however, and therefore we will dispense with any further discussion of the procedure.

Methods of Adding Garbage to Sewage

The three important methods of adding garbage to sewage are by central grinding stations with discharge to sewers, grinders at sewage plants with discharge to sludge digesters, and home grinders.

The first trial of central grinding stations was at Lebanon, Pa. in 1923. Since then such stations have been used at Baltimore, Md., Indianapolis, Ind., St. Louis, Mo., Gary, Ind., Lansing, Mich., Durham, N.C., Marion, Ind., and perhaps other places. The grinding stations have been located on trunk sewers either immediately ahead of the sewage treatment plant, or at more central locations throughout the city.

When the grinder is located at the sewage plant it has been found advantageous to discharge the ground material directly to sludge digesters, thus avoiding any effect on most of the other sewage treatment units. Both the advantages and disadvantages of this method will be discussed more fully later in this paper.

While central grinding stations may be of only theoretical interest to the operators of most sewage treatment plants, the last named method, namely domestic household garbage grinders, should be of interest to every sewage plant operator. The City of Butler, Pa., has an ordinance which prohibits the installations of these household grinders and I am told that Fond du Lac, Wis., is the only city west of Butler that has a similar ordinance. I mention this to demonstrate the apparent widespread acceptance of these units.

Central grinding stations will not eliminate the individual garbage cans or the disagreeable and unsightly parade of garbage collection. On the other hand domestic grinders will completely eliminate much of that odorous and fly beridden nuisance.

At one time human wastes were collected daily in wagons and hauled to points of disposal. Today, no civilized country would countenance such a procedure. Perhaps at some far distant time the attitude of the public to garbage collection will be the same as is the present day public's attitude to the collection of human wastes. When that time comes, domestic garbage grinders will no doubt be as universally used as is water carriage of human wastes today. However, I believe that time to be in such a far distant future that present day designers or operators need not be concerned about the use of garbage grinders in more than half of the homes.

*Presented before the Pennsylvania State College Sewage Works School and here published by permission.

Central Grinding Stations

The grinders used at central grinding stations are of two types, either the hammermill type, as manufactured by the Jeffrey Manufacturing Co. and Gruender, or the rotary shear type, as manufactured by Mitts and Merrill. Power consumption varies with the fineness of the grind. Early experiments with some of these units only attempted to grind the garbage so it would pass a ¾-in. mesh screen. However, experience indicated that a finer grind was desirable and now, so far as the writer knows, present day units attempt to grind all material so it will pass a ¼-in. mesh screen. Power consumption ranges from 4 to 5 kilowatt hours per ton of garbage ground. Jeffrey makes five different sizes of units ranging from 2½ to 30 tons per hour in capacity. The smallest unit is powered by a 10 horsepower motor and the largest unit by a 100 horsepower motor. The smallest Gruender grinder has a capacity of 6 tons per hour and is powered by a 30 horsepower motor. The Mitts and Merrill grinders range in capacity from 6 to 24 tons per hour and have motor sizes ranging from 40 to 150 horsepower. All three makes have provisions for segregating tramp metal. However, tin cans are not included in this category, and are cut up with the wet garbage in event they enter the units. Grinders of the hammermill type have difficulty in handling such material as corn husks or poultry feathers.

Water is added to assist in flushing the ground materials through the machine, as is the case of the domestic grinders. Water consumption ranges from 500 to 700 gallons per ton of garbage ground, depending upon whether the units are operating at below capacity, or their rated output.

C. F. Keefer of Baltimore, Md. states that the noise created by central grinding stations can be heard for distances of 400 to 500 feet, but concludes that the odor nuisance from such stations is much less than that from either incineration or garbage reduction.

Domestic Grinders

Although the General Electric Co. "Disposall" is the best known household garbage grinder, there are more than a dozen different manufacturers of kitchen garbage grinders and at least four manufacturers of units for restaurants and hotels. Several of the household type manufactures are licensees of General Electric. Specifications for one of these household units supplied by one of the manufacturers include the following:

"The food waste shredder shall discharge shredded wastes at a reasonably uniform rate, in a fluid form, which shall flow readily through an approved trap, drain line or soil line in a manner which will prevent clogging or stoppage of drain line. The food waste shredder shall shred food waste to a uniform size to meet the following requirements: 100 per cent shall pass ½-in. screen, at least 90 per cent shall pass a ¼-in. screen, not over 5 per cent shall pass a No. 40 sieve. Screens shall be the U. S. Standard and weight shall be taken on a dry basis."

The units handle about one pound per minute of ordinary household garbage. During grinding, water is added at the rate of 1½ to 2½ gpm.

It has been suggested that as home grinders develop in popularity, ordinances prohibiting their use will be as difficult to enforce as are our present ordinances prohibiting the introduction of roof drainage into sanitary sewers. At present, these domestic units are still too high priced to be installed in any but the more expensive homes. However, many people expect that their use will some day become as widespread as our electric refrigerators today.

In the May, 1949, issue of *Water & Sewage Works*, Mark Owen traces the development of radios, refrigerators, automobiles and similar units and draws a comparison between those units and domestic grinders. It is his estimate that by 1965 domestic grinders will be used in approximately 45 per cent of the homes, and that from then on their usage will increase until they will be found in from 50 to 60 per cent of the homes. It should be noted, however, that radios, electric refrigerators and automobiles are still not used in all homes, and therefore, unless home grinder use is made compulsory, there is no reason to expect that household grinders will ever be universally used.

Quantity and Character of Garbage

It must be borne in mind that only wet, or green, garbage can be added to sewage. It should preferably be unwrapped, relatively free from paper, and fit to feed hogs. Ramsey states that in an average city wet garbage constitutes 65 per cent of the total tonnage of refuse. At Los Angeles, where there are little or no ashes, and combustible refuse is not collected, wet garbage constitutes 77 per cent of the total tonnage of refuse collected. Thus it appears that we would still have dumps and periodical visits of the rubbish man, even though domestic garbage grinders were universally used.

Before considering the effect of the admission of ground garbage to sewers or sewage treatment plants, it is necessary to have some idea of the amount of such garbage that might be added. A rather extensive review of the literature indicates that the average annual production of green garbage ranges from about 0.4 to 0.8 lb. per capita per day. Some of this variation may be due to variations in moisture content, which has been variously reported from 60 to 98 per cent. For the purposes of this discussion I have assumed a per capita green garbage production of 0.6 lb. per day, containing 75 per cent moisture.

The per capita production of garbage is subject to greater seasonal variations than is the per capita production of sewage solids. For example, at Columbus, Ohio, where the average production of garbage was 0.68 lb. per capita per day, over a 12 year period, the peak for a 30 day period during that time was 1.37 lbs. Maximum production occurs during the summer when green vegetables are most plentiful and usually is at a minimum during the month of February.

The literature contains numerous analyses of garbage, many of which do not agree. This is not surprising; in fact,

there is no more reason to expect various analyses of garbage to agree than there would be to expect various analyses of sewage or sewage sludge to agree. In the accompanying table is presented more or less typical analyses of all three substances:

Comparison of Character of Garbage with Sewage and Sludge

	Pounds Per Capita Per Day		
	Ground Garbage	Sewage	Primary Sludge
Total Solids	0.15	0.55	0.12
Total Volatile Solids	0.13	0.32	0.08
Suspended Matter	0.10	0.20	-----
5 Day B.O.D.	0.08	0.17	-----
Fats and Greases	0.03	0.05	0.03
Nitrogen	0.002	0.04	0.003
Moisture	0.45	-----	2.28
Total (Moisture + Total Solids)	0.60		2.40

Even a casual inspection of that table must make it evident that the universal admission of ground garbage to sewage is bound to materially increase the burden on sewage treatment plants or receiving streams. The table is somewhat misleading in that the figures for ground garbage are based upon the assumption that the garbage is ground without the addition of water, while as above stated, this is not the case, either for domestic grinders or for central grinding stations. Water consumption with domestic grinders ranges between 1 and 2 gallons per capita per day. The water consumption of central grinding stations averages about the same, if it is assumed that 0.6 of a pound of green garbage per capita is produced and that water consumption ranges from 500 to 700 gallons per ton of garbage ground. This water dilutes the garbage so that instead of having an initial solids content of 25 per cent as assumed in the accompanying table, it would have a solid content of only about 7 per cent.

Effect of Garbage on Sewage and Sewers

The figures in the table indicate that if all garbage from a community were ground and added to the sewage, that the suspended matter and B.O.D. of the raw sewage would be increased approximately 50 per cent. Since domestic grinders will not be located in all of the homes, the increase resulting from their use will be proportionately less. However, the information previously given on water usage indicates that even were all garbage of a community to be ground, either by domestic grinders or in central grinding stations, the quantity of sewage would be increased only about 1 or 2 per cent, (based upon an assumed sewage flow of 100 gallons per capita per day). Thus it is evident that so far as size or capacity of sewers is concerned, the grinding of garbage and deposition into those sewers will have no effect.

Experience with domestic grinders has shown that the admission of finely ground garbage to house plumbing does not cause clogging in them; in fact, there is a tendency for the garbage to keep the inside of the pipes clean.

Normal domestic sewage and most industrial wastes are extremely dilute. For example, a flow of 100 gallons per capita, containing 0.2 of a pound of suspended matter would have a suspended solids content of 250 ppm. Even if all garbage were ground and added to the sewers, the suspended solids content would only be about 360 ppm. In the design of sewage structures, engineers apply the same laws of hydraulics to the flow of sewage as are applied to the flow of water. Water which carries suspended matter continues to flow as water until the concentration of suspended particles become so great that they touch one another in the fluid.

Sewage is so dilute to start with that it does not seem possible that a 50 per cent increase in suspended solids would cause any more deposition than occurs in normal sewage. Therefore, if a sewer system is free from deposits before the admission of garbage, it is reasonable to expect that it will remain so after the addition of ground garbage. However, if troubles are now experienced with deposition of sewage solids in certain portions of a sewer system, the addition of ground garbage may be expected to increase the amount of deposition at those particular localities.

Furthermore, inasmuch as garbage is higher in volatile solids than is sewage, the volatile content of those deposits would be increased, thus increasing the putrescibility and the likelihood of creating obnoxious odors. The necessity for flushing sewer systems would be increased and, in event the frequency of such flushings was not stepped up, sewage reaching the treatment plant would be more septic than it had been in the past. These troubles might warrant the exclusion of ground garbage from sewage collection systems. The blame, however, should not be placed on garbage grinders or garbage, but upon the inherent faults in the design or construction of the sewage collection system.

Even well designed sewer systems are troubled with deposition of solids at the upper ends of laterals where the volume of sewage is too small to maintain adequate depths of flow and hence solids become stranded along the pipe. It is to be expected that if domestic grinders are installed in homes tributary to the upper ends of these lateral sewers, that such difficulties will be increased. Flushing would be the only remedy.

After considering all of these factors, it seems reasonable to conclude that there should be no objections to the admission of properly ground garbage to a well designed and constructed separate sewer system. Such may not be the case with a combined system. Most combined systems are designed with storm water overflows which come into operation whenever the total flow exceeds 2 to 3 times the peak dry weather flow. The theory being that the overflow at that time is so low in suspended solids and B.O.D. that it has no deleterious effect upon the receiving stream which presumably is also a flood stage. If, however, all the garbage of the community has been ground and added to this sewage, then its B.O.D. and suspended solids content will be increased 50 per cent, and hence the B.O.D. and suspended solids content of the storm overflow would be correspondingly increased. Whether or not such an increase would cause objectionable conditions in the receiving stream is a matter for individual study in each locality.

Effect of Garbage on Grit

Now let us consider the possible effect of the addition of ground garbage to sewers upon the various sewage treatment plant structures. First let us consider grit chambers. Carpenter, et al, states, "that where the municipality collects the refuse, it will be difficult to educate householders to separate the garbage from foreign materials. In cities where garbage is disposed of by feeding to hogs or reduction, large amounts of metal and glass are found in the garbage. Unless such materials are removed before the garbage is ground, grit chambers in existing plants may have to be extended."

At Indianapolis, where all garbage was ground and discharged into the sewage for seven months, the garbage was hand picked for tin cans, heavy bones and large pieces of metal. The picked material constituted 3.1 lb. of bones and 3.4 lb. of metal per ton of green garbage. Despite this hand picking, the garbage produced 38.2 lb. of grit (containing 28 per cent water) per ton of green garbage. This constituted an average increase of 23 per cent in grit collections for the Indianapolis plant. Green garbage collections at Indianapolis amount to only 0.43 lb. per capita per day. In cities where the quantity of garbage is higher, the amount of grit will also be higher. On the basis of 0.6 of a lb. of green garbage per capita, the increase in grit might have been 35 instead of 23 per cent.

At Finley, Ohio, where a central grinding station is used, garbage additions are made at the rate of 1.1 ton per million gallons of sewage. Prior to operation of the grinding station, grit collection averaged 1.5 cu. ft. per mil. gal. of sewage, while since the operation of the grinding station, they have averaged 2.7 cu. ft., thus indicating an 80 per cent increase in amount of grit.

Garbage grit is largely bones, egg shells, etc. Its volatile content is higher than that of good grit and frequently it is much more offensive. Experience at Indianapolis showed that by grinding to pass ¾-in. mesh instead of ½-in. mesh that the offensiveness of the grit could be materially reduced. The use of grit washers will probably be found more necessary if central grinding stations are installed on trunk sewers.

It is to be expected that less grit will result from the grinding of garbage in domestic grinders than would be the case where central grinding stations are used. This statement is based upon the observation that it is just human nature to take better care of your own garbage grinder unit that you have paid for out of your hard earned money, than it is to worry about including large bones or tin cans in so-called green garbage which is to be delivered to the city's grinder.

Effect of Garbage on Sedimentation

The addition of ground garbage to sewage may affect the performance of primary settling tanks in three different ways: (a) the amount of scum produced, (b) tank efficiencies and quality of effluent, and (c) the kind and amount of sludge collected.

Experience has shown that the addition of ground garbage definitely increases the amount of scum forming on the top of primary tanks. However, the more uniform the additions of garbage and the finer its grinding, the less serious becomes the scum problem. It is generally recognized that all primary settling tanks should be provided with mechanical skimming devices. If this is done and garbage

additions are made at the uniform rate, or as uniform as might practically be obtained, it is not to be expected that the increase in scum formation will be serious. Screening of settled sewage through ½-in. mesh screen might be advisable to prevent floating solids causing trouble with secondary treatment devices. This scheme is now used at a number of sewage plants, particularly those having comminuters or bar screenings shredders, and causes no undue difficulty in operating problems.

As regards settling tank efficiencies, all investigators seem to agree that the addition of finely ground garbage increases the percentage removals of both suspended solids and B.O.D. by plain sedimentation, but there the similarity in published results ends. One investigator reports that these percentage increases in removals are so great that they completely offset the increase in solids and B.O.D. of the raw sewage, and therefore the settling tank effluent actually has as low, or a lower, B.O.D. content than it did prior to the introduction of garbage. Another investigator, however, reports that the addition of ground garbage to sewage may increase the B.O.D. of the settled sewage as much as 100 per cent. Most of these investigations were made on laboratory or small pilot plant scale. Results from existing sewage treatment plants are difficult to interpret because frequently the addition of ground garbage was not the only change made at the sewage treatment plant. Frequently central stations were constructed at the same time that secondary treatment processes were installed and thus return of secondary sludge or changes in the character of digester supernatant being returned to primary tanks might well account for some of the changes observed in the quality of settled sewage.

After reviewing all of the available literature, the writer has come to the conclusion that the addition of ground garbage to sewers ahead of the primary settling tank may result in a 5 to 10 per cent increase in the suspended solids content and a 15 to 30 per cent increase in the B.O.D. of the tank effluent. These figures apply to a municipality where all green garbage is ground. Obviously if domestic garbage grinders are installed in only a few of the homes, the resulting increase will be correspondingly less, and in fact, may be so small that it cannot be observed until such time as those grinders become more universally used.

As regards volume of sludge collected in primary settling tanks, the literature seems to indicate that in general the garbage solids have settling characteristics similar to those of the sewage solids and that therefore the solids content of the primary sludge will be about the same after the addition of ground garbage that it was before. Because of the increase in total solids, however, there will be a corresponding increase in volume of sludge. In fact, as the figures in the table on garbage characteristics would indicate, and as confirmed by several statements of various investigators, it appears reasonable to expect that the volume of sludge would be increased 100 per cent as a result of ground garbage additions from the entire community. Since the garbage solids are higher in volatile matter than are the sewage solids, the increase in volatile content of the sludge will be even greater, perhaps 150 to 175 per cent.

Effect of Garbage on Chemical Treatment

When garbage is ground much of the matter which was originally in suspension goes into either true solution or colloidal dispersion. The more distant the grinding point above the sewage plant, the greater will be the amount of material dissolved. Rudolfs has found that actually a considerable portion of this dissolved material is in true solution rather than colloidal dispersion and as such is not amenable to chemical coagulation. Therefore, chemical precipitation will not effect a B.O.D. reduction as great on mixtures of sewage and ground garbage as it will on sewage alone.

Rudolfs also found that the addition of ground garbage to sewage increased the amount of chemicals required for coagulation. When iron salts were used as the coagulant, the addition of garbage always increased the iron demand at least 5 to 10 ppm. The importance of pH adjustment with iron appeared more pronounced in sewage garbage mixtures than in sewage alone. Optimum coagulation occurred at a pH of 8.5 to 9. On the other hand, where alum was used as the coagulant, the addition of garbage to the sewage made less difference in the chemical demand. Optimum coagulation was at a lower pH.

Effect of Garbage on Secondary Treatment

In general, grit chambers and primary settling tanks are designed on the basis of sewage volume and since the addition of ground garbage makes very little increase in volume of sewage, little or no change in these structures are required to adopt them to sewage garbage mixtures, even though operating problems such as sludge quantities, grit quantities, or chemical coagulant requirements may be increased by the addition of ground garbage.

Now let us consider secondary or oxidizing methods of sewage treatment. Since the addition of ground garbage increases the B.O.D. of either settled or chemically coagulated sewage, and since these oxidizing treatments are designed partly, at least, on the basis of B.O.D. loading, it seems obvious that secondary treatment structures must be increased if ground garbage is to be added to the sewage. Obviously, the amount of increase is dependent upon the amount of garbage added. The effect of these additions of ground garbage upon the activated sludge process has been reported by a number of investigators. All seem to agree that the oxygen demand resulting from the addition of garbage is just as readily oxidized as is the normal oxygen demand of the settled sewage. They also agree that the addition of ground garbage does not interfere with nitrate production and that, providing aeration periods and air usage are adequate, it has no deleterious effect upon settling or oxidizing characteristics of the activated sludge itself.

Tolman has concluded that the addition of ground garbage to raw sewage would increase the required capacity of aeration tanks for the activated sludge process by 5 per cent, and the quantity of air required by 11 per cent.

Less research has been done on trickling filters. It is generally agreed, however, that the organisms responsible for oxidation on trickling filters are the same as those responsible for oxidation in the activated sludge process. Therefore, it seems logical to believe that mixtures of ground garbage and sewage may be as easily treated on trickling filters of adequate size as mixtures can be treated in suitable activated sludge plants. It is quite possible, however, that floating solids resulting from increased scum formation on primary tanks might cause difficulties with nozzle clogging on trickling filters unless screens are injected between the primary tanks and the filter distributors.

Where only primary treatment is practiced, the receiving stream is actually the secondary treatment or oxidizing unit of the complete sewage disposal system. Obviously, increases in B.O.D. or suspended solids of the settled sewage place a greater burden on the receiving stream. Whether or not it can handle that burden is a problem for local investigation in each case.

Effect of Garbage on Sludge Digestion

Repeated laboratory studies have shown that the organic matter in garbage is digestible regardless of whether such material is digested alone or mixed with sewage sludge. Experiments on the digestion of garbage solids alone indicated that there was a tendency for the formation of acid conditions and that frequently the pH dropped so low that digestion was seriously retarded or inhibited.

Inspection of the table of analyses previously given indicates that nitrogen constitutes only about 1.5 per cent of the volatile matter in garbage, as compared with almost 4 per cent in primary sewage sludge. Quite possibly there is not enough nitrogen in the garbage to maintain the necessary alkalinity for good digestion. In the case of digestion of a garbage-sewage sludge mixture, although the nitrogen to volatile matter ratio is considerably lower than it is in the sewage sludge alone, it is apparently high enough so that little or no difficulty is encountered in maintaining suitable alkalinity and pH for sludge digestion.

Ground garbage has been successfully digested with sewage sludge in ratios varying from 0.3 up to 1.5 parts of dry volatile garbage solids per part of dry volatile sewage sludge solids.

Data indicate that at least 16 cu. ft. of gas may be expected per pound of volatile garbage solids digested. This compares with estimates of 15 to 18 cubic feet per pound of volatile sewage solids digested. As might be expected, the optimum temperature for digestion of sewage garbage mixtures is the same as for the digestion of sewage solids alone. Babbitt had little or no success in digesting garbage sewage mixtures in unheated Imhoff tanks during the winter months, but was quite successful in digesting it in heated separate digestion tanks. Obviously, seeding and mixing of incoming raw sludge with actively digesting material is just as necessary when digesting the mixtures as it is when digesting sewage sludge alone, but again there seems to be considerable difference of opinion as to whether or not mechanical mixing and stirring devices are necessary and if so, which type of device is best suited to the problem.

While there is every reason to believe that garbage may be successfully digested when mixed with sewage or sewage sludge, it does not follow that the addition of garbage to sludge digestion facilities already operating under a heavy load would cause no serious difficulty.

In the operation of sludge digestion tanks, there is no single unit by which the loading on a particular tank can be measured. Loading is a function of both the volume of the raw sludge, and the weight of dry volatile solids introduced into the tank. Obviously more volatile garbage solids will require digestion if the ground garbage is discharged directly to the digester than if it is discharged to the trunk sewer.

Various investigators have reported that when the ground garbage is fed to the sewage, the quantity of garbage reach-

ing the digester will vary from 40 to 75 per cent of the total garbage additions. If we assume this percentage to be 67 per cent, then it is obvious from the foregoing table that the direct addition of ground garbage to the digester would increase the quantity of dry volatile solids to be digested 163 per cent as compared with about a 100 per cent increase if the ground garbage was added to the raw sewage ahead of the grit chamber.

On the other hand, even when allowance is made for the addition of water during grinding, the ground garbage will contain 7 per cent or more, solids as compared with 4 to 5 per cent solids in normal primary sewage sludge. Therefore, the total volume of raw material charged to the digester will be no greater if all garbage were ground and delivered directly to the digester than it would be were the garbage delivered to the raw sewage, and only the settleable portion removed from the primary tanks to the digester. On the basis of the previously given analysis, these volumes would be almost identical; many investigators claim that there is actually a reduction in volume of material charged to the digester when the ground garbage is delivered directly to those tanks.

In any specific instance, complete information on the quantity and character of both the local garbage and sewage should be obtained before deciding upon the digestion capacity required for handling the mixed garbage-sewage sludge, but in general, the addition of all of the garbage of a community will approximately double the digester capacity that would be required for digesting sewage sludge alone. At complete sewage treatment plants, where digester capacity is considerably higher due to the necessity of digesting secondary as well as primary sludge, the addition of garbage would not necessitate such a big percentage increase in digester capacity.

Although the digester capacity required for handling garbage-sewage sludge mixtures will be about the same regardless of whether the ground garbage is added directly to the digester or to the raw sewage, it should be noted that the quantity of gas to be expected from such digestion will be considerably greater if the garbage is added directly to the digestion tanks. Assuming the same degree of digestion in either case, this increase might be 30 per cent.

Lansing, Mich., was one of the first municipalities to adopt the practice of grinding all green garbage and discharging it directly to sludge digesters. Delivery of ground garbage was made by pneumatic ejectors. The plant was completed early in 1938 and included the activated sludge process, as well as primary sewage treatment and garbage grinding. Soon after it went into operation considerable difficulty was encountered with the deposition of grit in digested sludge lines and the clogging of ball valves on digested sludge pumps. This grit resulted from the grinding of bones, egg shells, fruit pits and bottle caps originating in the garbage. The operators found it necessary to flush all digested sludge lines daily and each day removed about 15 to 20 cu. ft. of such garbage grit from those lines. As a result of that experience, most plants handling ground garbage now either discharge that material to the sewage ahead of the grit chambers, or provide special facilities for removing the garbage grit before it is introduced into the digester. However, ground garbage has been successfully handled in the digestion tanks at Goshen, N.Y., without prior removal of garbage grit. There the digestion system is of the two stage type. Ground garbage is delivered directly to the primary digesters by pneumatic ejectors. When sludge is transferred from the primary to the secondary digester it first passes through a manhole before entering a second ejector. Whenever the operator believes it is necessary, he places a wire mesh screen at the point where the primary digester discharge line enters the manhole and in this manner removes the larger inorganic solids. This is done occasionally and is not a regular routine procedure.

Henry Taylor, designer of the plant, believes that the removal of garbage grit is unnecessary if a blow-off head of at least 10 ft. is provided at the primary digester sludge draw-off line and if facilities are provided between the two digesters for removal of the coarser, non-organic material.

Two methods have been used for removing grit from ground garbage before it is introduced into the digestion tanks. The method used at Marion, Ind., provides for the delivery of ground garbage to a pit where water is added to bring the solid content down to approximately 5 per cent. The contents of the pit are then agitated with compressed air which washes the garbage, causes most of the organic matter to float, while still permitting the grit to settle to the bottom. After a few minutes of such agitation all of the contents of the tank, except the deposited grit, is pumped to the digesters.

The other method that has been used is to pass the ground garbage through a grit washer similar to the Jeffrey jig-grit. The overflow from such units, which includes most of the organic matter in the garbage, passes to a wet well from which it is pumped to the digesters. While either of these methods is successful in eliminating grit from the ground garbage, both of them dilute it with additional water so that the material delivered to the digester contains only 4 to 5 per cent solids instead of perhaps 7 to 10 per cent solids that might have been obtainable had grit removal not been considered necessary. Obviously this materially increases the volume of raw sludge delivered to the digester and therefore produces an additional burden on sludge digestion and increased digester overflow liquor. In fact, the solid content of the deliveries to the digester in this case would be no greater than it would be had the ground garbage been delivered directly to the raw sewage ahead of the main grit chambers. Therefore, the only advantage gained by direct additions of garbage to the digester in this manner is the elimination of the previously mentioned effect of ground garbage on chemical precipitation or oxidizing processes of secondary sewage treatment.

Effect of Garbage on Sludge Drying

Rudolfs has investigated the dewatering of fresh and digested sewage and sewage-garbage sludges on vacuum filters. He concluded that fresh sludge from sewage-garbage mixtures can be readily dewatered on vacuum filters with the aid of ferric chloride before or after digestion. The ease of dewatering such sludges after digestion appears to depend on the same factors which determine the rate of dewatering digested sewage solids alone.

In general, all investigators agree that digested sewage-garbage sludge has the same general characteristics as digested sewage sludge, and all experiences indicate that it may be as easily dried on either vacuum filters or sludge drying beds as can be the digested sewage sludge alone. It should be obvious, however, that sewage plants handling ground garbage will require larger drying facilities than would be the case if they received no garbage at all. Even though garbage is high in volatile solids, not all of that volatile matter will be digested and therefore there will be a very material increase in quantity of digested sludge to be dried.

Conclusions

In conclusion, it may be stated that garbage may be ground and added to sewer systems without creating any serious problems, providing such systems, including the collection system as well as the treatment plant, are adequately designed and constructed to receive such material. Where collecting sewers are already subject to solids deposition and putrefaction, or where sewage treatment facilities are already operating at close to maximum capacity, a municipality may be entirely justified in making every effort to exclude garbage from its sewer system.

So far as central grinding stations are concerned, it is obvious that they should only be installed after careful consideration of the condition of the existing sewerage system and the costs of enlarging and operating that system to handle the garbage has been compared with the cost of constructing and operating incinerators or other methods of garbage disposal equally satisfactory from a sanitary viewpoint. So far as domestic garbage grinders are concerned, one may expect it to become increasingly difficult to prevent their installation as the public becomes more familiar with their convenience, and more widespread use results in decreased initial cost of household grinders. Therefore, designers and all others charged with the maintenance or operation of sewer systems, should recognize the probability of gradual increases in sewage treatment loads that are likely to result from the widespread use of these units.

Although existing sewage treatment plants can be altered or enlarged if necessary to facilitate the handling of ground garbage, the same cannot be said for the ability of a receiving stream to handle an additional load of pollution. Thus, it is conceivable that in some cases the admission of ground garbage to the sewage system will necessitate a higher degree of treatment than would be the case if garbage were disposed of by incineration or some other method.

In event the use of central grinding stations is under consideration, the question will naturally come up as to whether such stations may be better placed at the sewage treatment plant or at some more central location providing shorter hauls by the garbage collection vehicles. Time does not permit mention of all of the factors to be considered in arriving at such a decision. I do wish, however, to call attention to one factor which might be overlooked. The practice of using sludge digestion gas for power generation is well known and as the previous discussion pointed out, the addition of garbage to sewage might more than double the amount of gas available for power production, heating and the like. In the writer's opinion, the power to be obtained from such gas might better be used for operating pumps, blowers, or other units that operate practically continuously, than for driving garbage grinders that operate only intermittently. Garbage grinders have extremely large motors. The starting of such large motors would create excessive loads on generating equipment that might otherwise be large enough to supply the power required at the treatment plant.

SLUDGE DIGESTION TANK HEATING—A PANEL DISCUSSION*

GEORGE E. SYMONS, CHAIRMAN
Managing Editor
Water & Sewage Works, New York, N. Y.

CHAIRMAN Symons: It would be well to begin with some fundamentals of sludge heating and to define any controversial terms of statements as we proceed. The first question is: Why are digesters heated?

P. E. Bardet, Engineer-in-Charge, 26th Ward Sewage Treatment Plant, New York City: Digesters are heated to obtain sludge digestion temperatures most favorable to the bacterial life causing digestion.

Chairman Symons: What is the optimum temperature for good digestion?

A. J. Fischer, The Dorr Company, New York, N. Y.: In the mesophylic range, the one commonly used in practice and considered to be from 70° to about 100° F., the optimum temperature for good digestion is about 95° F. The other, or thermophylic range, is normally considered to be from 130° to 140° F.

P. J. Cerny, Pacific Flush Tank Company, New York, N. Y.: One comment on the mesophylic range: there are indications of an optimum temperature of 90° in one place, 95° in another. Several years ago Fair and his co-workers did some work, which developed the theory that the actual optimum temperature for any given plant depends on the rate of loading of digesters; in other words, the temperature should be coordinated with the rate of introducing the food supply into the tank—so many pounds of dry solids per cubic foot per day.

Mr. Fischer: I disagree. The rate of loading has nothing to do with optimum temperature.

Chairman Symons: It is possible to have the best digestion at a certain temperature in one plant, and at a slightly different temperature in another. In the first laboratory feeding experiments on the determining of optimum ranges, it was found that 92° was best. This temperature proved to be all right at Decatur, Ill., but other plants have found that 88° or 90° is better for their particular conditions. The optimum range is where the best over-all operation is obtained, somewhere around 90°.

Mr. Fischer: Probably no one will quarrel over a couple of degrees; the temperature cannot be controlled that closely. There have been cases where operation at the optimum temperature has been undesirable because of the greater scum formation, particularly where materials of a fibrous nature are present. Danbury, Conn., originally operated at 90°; at 70° to 80° there was less scum. The same thing happened at Kitchener, Ont.

Chairman Symons: Raising the temperature also has reduced scum formation in many cases. Each individual case is a problem in itself.

C. C. Agar, Senior Sanitary Engineer, State Dept. of Health, Albany, N. Y.: Can digestion temperatures be changed from one range to another?

Mr. Fischer: Yes. As shown by some experimental work at Jackson, Mich., there is very little lag in going from the mesophylic to the thermophylic range. If, however, it is necessary to reduce temperatures from the thermophylic to the mesophylic range, there may be a period of about a month before conditions are suitable for further digestion. With two tanks in series, the first can be run at the thermophylic range and the second at the mesophylic, provided there is seed material in the second tank. The digestion lag in going from the thermophylic to the mesophylic range is due to the differences in the organisms involved. During mesophylic digestion there are many thermophylic organisms present, but in a dormant state. In raising the temperature from the mesophylic to the thermophylic range, most of the mesophylic organisms are destroyed. Therefore, when temperatures are lowered again considerable time elapses before digestion can again proceed.

Chairman Symons: That brings up the next question: How may sludge digesters be heated?

C. R. Velzy, Consulting Engineer, New York, N. Y.: The two basic systems of sludge heating are external and internal, depending on whether the sludge is heated before or after introduction into the digester.

Mr. Fischer: For internal heating of digesters there are two general types of heating coils. One depends on thermal circulation; the other, on mechanical circulation. There are also warm wall digesters, where the heating coils are imbedded in the walls or floor. Other methods consist of live steam injection into the tank, submerged combustion chambers, and immersion heaters. The heating coils may be separated into three categories—circumferential coils, vertical coils, and rotating coils. Rotating coils have not been used in the United States, but are used in Europe. One type is the regular coil about 2 to 3 ft. in diameter and 10 ft. long as used by Imhoff; the other, is mounted on a mechanism.

Hot water heating has also been used; that is, injection of hot water into the tank. It was not too satisfactory, although the "washing" of the sludge appears to be a good thing from the standpoint of improving the filtering characteristics. Subaqueous burning, as far as known, has never been used inside a digester. I can't see how it would work, because the carbon dioxide must be removed.

Mr. Cerny: External heating is accomplished by any of the various water-to-sludge heat exchangers; by preheating of raw sludge with live steam; by subaqueous burning, or burning gases directly in the sludge; or by immersion heaters. The water-to-sludge heat exchangers may be of the concentric pipe type or of the ordinary coil-in-tank type for preheating by hot water or hot gas.

Chairman Symons: The several methods of application or devices for accomplishing both basic types of heating are certainly not all equal in advantages and disadvantages. How do they compare?

G. W. Moore, District Sanitary Engineer, State Dept. of Health, Rochester, N. Y.: For horizontal internal coils the greatest disadvantage is one common to all methods of internal heating; the tank is not dewatered frequently enough to know what is happening to the metal. The greatest advantage is that it is the simplest method of heating digesters, both from the standpoint of design and operation. This type of coils makes full use of convection currents, being placed at the optimum location in the tank.

Mr. Velzy: A major disadvantage with many horizontal coils has been that the coils become loaded with sludge, which deposits at the side of the tank and doesn't flow to the center. In some cases this physical loading of the coils with solids has caused failure of the coils.

Chairman Symons: What about vertical internal coils?

Mr. Fischer: Their biggest advantage is that they can be removed from the tank for inspection and cleaning without draining the tank. In addition, they are not subject to failure by solids loading, such as previously mentioned for horizontal coils.

Mr. Cerny: A disadvantage common to practically all internal heating methods is inability to control the temperature within narrow limits. For instance, when raw sludge is put into the tank there not only are cold zones in the tank contents, but also the average temperature will drop and will pick up slowly. Optimum digestion is obtained only where temperature variations are controlled within a quite narrow range.

Mr. Bardet: From the viewpoint of design all internal piping has another disadvantage. It is designed for the area needed and for the other factors involved, including the coefficient of heat transfer for the piping material involved. In time—and a fairly short time, at that—the coefficient changes. There is no way to make up for this variation in the coefficient.

Chairman Symons: What are the advantages and disadvantages of submerged burning—that is, in internal heating?

Mr. Fischer: An engineer, as a rule, objects to having an open flame around a digester because of explosion hazards. Therefore, as previously mentioned, subaqueous burning has not been used. Similarly, it is difficult to sell the idea of the immersion heater because of the open flame—even though the flame is confined to a pipe or other chamber—as it is argued that if the chamber burns out the open flame would operate directly in the tank, exactly as if it were a submerged combustion unit.

An interesting experience with an immersion heater was had in Mansfield, Ohio, in 1946. The idea looked attractive from the cost standpoint. However, that particular unit was near the top of the tanks, so that it was partly in the scum layer, which insulated an area around the pipe coils and caused them to burn out rapidly. A similar installation at Baltimore, Md., had been operating without trouble for about a year. In that case, however, the unit was submerged about 12 ft. Also, the tank was lightly loaded, as a result of which no scum formed. In time, the coil of the Baltimore unit will probably cake up, but so far it has been successful.

The Baltimore unit consists of a central pipe, to which two U-pipes are connected. The flame is in the center pipe, the resulting hot gases passing through the two outer legs. The temperature in the unit is high enough so that no condensation is possible. In the Mansfield installation only a single U-tube was used.

At Jackson, Mich., an injector method was used to suck into the sludge hot gases formed by burning gas in a submerged combustion chamber. This is similar to the method proposed for use at Philadelphia, Pa., except that the Philadelphia unit will

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bring the hot gases in contact with the sludge outside of the digester. Although sludge heating was quite satisfactory at Jackson, the gases, which had to be vented, were extremely odorous—the worst I have ever smelled. I believe that at Philadelphia some provision is being made for burning these gases to destroy the odor.

Chairman Symons: What about radiant heating or warm wall heating?

Mr. Cerny: Although there aren't much operating data available for this type of installation, the literature seems to indicate certain obvious disadvantages. Coils are imbedded in the tank wall, which means that there is heat leakage. To minimize these losses the outside of the tank must be pretty thoroughly insulated. Also, there is a large number of heating coils to place in the walls, especially in heavily loaded digesters. Another problem is what to do if leaks develop in the heating coils inside the walls.

M. M. Cohn, Editor, Sewage Works Engineering, New York, N. Y.: If a wall crack occurred simultaneously with a failure in the radiant heating piping, it would be necessary to dig out the piping, a difficult job, or seal the concrete itself to control the leak within the circumference of the pipe. There is considerable experience in radiant heating of buildings, and there may be some merit for its application to digesters. In one plant, a great advantage is claimed for having a radiant heated floor in the service shop while repairing a piece of equipment.

Mr. Fischer: To me the term "radiant heat" as applied to the warm wall digester is a misnomer. For that matter, coils imbedded in a driveway or a dwelling floor do not supply radiant heat such as is supplied by electric wall panels, which actually "shine" heat on the body.

I would like to mention another internal heating method, which in my opinion is the most efficient method of heating a digester—that is, injection of live steam into the tank contents. Its disadvantages are that if the water supply is hard it must be softened, 100 per cent make-up water is required, and water may have to be purchased because of the high quality required in the boiler. The supernatant decant is negligible, but the tank contents must be stirred as there is a tendency for the heated sludge to remain at the top of the tank. This method was successful at Jackson, Mich., but we soon found out that unless the steam was injected far enough down in the tank contents (12 ft.) it sounded like a machine gun.

Mr. Bardet: Mr. Fischer, using live steam heating and no stirring, found high temperatures at the top of the tank. We recently tried the same scheme at the New York 26th Ward plant and found the lower temperatures at the top of the tank. The dome plate was removed and the connections made for live steaming. No attempt was made to measure the gas, so the full efficiency of the test is not known. However, after steaming the tanks for an extended period then allowing it to rest for one day, temperatures at the top of the tank were about 88°; at the bottom, about 105°.

Mr. Moore: In using live steam there is always the danger that the safety devices are not working. A poorly working vacuum breaker may permit backsiphonage to foul the boiler, or perhaps crack it.

Mr. Fischer: Another disadvantage to be considered in steam heating is that local unions may insist on employment of a stationary engineer to operate the boiler.

G. F. Fynn, Chief Chemist, Buffalo (N. Y.) Sewer Authority: Quite a few years ago we injected live steam into a tank by means of a pipe. The live steam made the top sludge quite fluid, so that the pipe finally floated up from its 10- or 12-ft. depth to the surface. There was practically a condition of distillation in the tank, and when the gas pipes got pretty hot we stopped using steam.

Chairman Symons: That brings us to the advantages and disadvantages of the various methods of external heating.

Mr. Fischer: There are two large successfully operating plants on the West Coast using live steam externally, the largest being in Los Angeles County. The same disadvantages apply for applying steam heat externally as for the internal application—there must be good submergence, the boiler water must be softened, and 100 per cent make-up water must be supplied.

Subaqueous burning and immersion heaters face the same objections in external heating as in internal heating. Injection of hot gases directly into the sludge has already been mentioned in connection with internal heating.

Chairman Symons: The remaining methods of external sludge heating are represented by commercial heat exchangers of various types. Before discussing these, however, there is one design that should be mentioned, presented by Mr. Velzy.

Mr. Velzy: The design referred to was made for the proposed Hunt's Point plant in New York City. It has not been built, and may be outmoded by the time it is built. At any rate, it is a simple concentric pipe system following the same principle as other heat exchangers now on the market. There is nothing unusual about it except that it is made of aluminum tubing to decrease weight and increase heat exchange coefficients.

Mr. Cerny: P.F.T. has developed and is marketing a two-pipe (concentric) heat exchanger of the type just described. There is one general comment that should be made with regard to any hot water-to-sludge heat exchanger—in the design of such a unit, provision must be made for eliminating any possibility of the heating water becoming contaminated with sludge. This is to protect the gas engines or boilers against costly damage. As experimental work has shown that welded joints are not dependable for the necessary separation, a double-gasketed joint with air gap between has been developed.

The same type of joint is used in the P.F.T. combination boiler and heat exchanger, which is applicable to the majority of installations. In this unit the inlet temperature ranges from a minimum of about 50° F. to a maximum of about 95° F., depending on whether raw sludge, digester liquor, or a mixture of the two is being heated. The outlet temperature is a few degrees higher. No adjustment of the air damper is required when switching from one fuel to the other, as the oil and gas burning rates are controlled to require the same rate of air for combustion. As far as I know this is the only dual-fuel burning equipment that is completely automatic, even to the extent of automatic preference for digester gas as the fuel.

Mr. Bardet: What is the sludge temperature at the outlet? Is the sludge overheated so as to maintain a fixed temperature in the digester?

Mr. Cerny: The sludge is overheated. As for the outlet temperaeture, that depends on many factors. With a unit rated at 100,000 B.t.u. per hr. and a circulation rate of 75 g.p.m. through the sludge tubes, the minimum rise would be a little over 2.5° F. With a unit rated at 1,000,000 B.t.u. per hr. and a sludge circulation rate of 150 g.p.h., the minimum rise would be a little over 13° F. These values are for heating only digester liquor at an inlet temperature of 95° F. They are predicated further on a definite temperature of heating water and a definite degree of fouling of the sludge tubes.

Mr. Fischer: The Dorr Company's "spiral" heat exchanger consists of two intermeshing spiral passageways. The heating medium, which may be hot water or steam, goes through one spiral. Countercurrent heating is accomplished by sending the sludge through the other spiral in the opposite direction. All auxiliary elements are standard—that is, the hot water or steam boiler, the hot water circulating pump, and the sludge pump. The sludge pump handles intermediate tank liquid. There is no advantage in heating raw sludge, as it is pumped only about 1 hr. a day; therefore, to heat it to tank temperature, the heat exchanger would have to be 24 times as large as now required.

Mr. Cerny: We definitely recommend preheating the raw sludge, but in such a manner as to eliminate the very real objection just pointed out. For example, it is suggested that raw sludge be pumped at the lowest practicable rate, which amounts to 24-hr. continuous pumping for the larger plants and frequent and prolonged pumping periods throughout the 24 hr. for the smaller plants. The raw sludge is mixed with circulating digester liquor ahead of the heater, resulting in near optimum temperature of all material entering the digester.

This method has two decided advantages. In the first place, temperature variations within the tanks are controlled to a minimum and cold zones are completely eliminated. The importance of these factors has been pointed out previously. In the second place, the food supply and the organisms responsible for the reduction of this organic material are intimately mixed and discharged simultaneously into the digesters.

The objective is to obtain the highest possible efficiency of the anaerobic sludge digestion process, thus resulting in more economical structures. This can only be accomplished by providing the means, operating procedures, and controls for maintaining an active balanced biological population. Two of the primary requirements for this condition are uniform optimum temperature and a uniform and accessible food supply.

C. J. Velz, Head, Civil Engineering Dept., Manhattan College, New York, N. Y.: Two different types of heaters have been described. What would be the effect of lowering the digester temperature by pumping unheated raw sludge as recommended by Mr. Fischer?

Mr. Fischer: The temperature difference caused by putting raw sludge into a normal digester without preheating is negligible.

Mr. Cerny: The temperature difference is there, but localities must be checked within the digester—local areas and zones are chilled. With increased loadings the effect becomes increasingly significant.

Mr. Fynn: We find considerable variation in temperature at different points. Although we have only one point of taking temperatures on a recorder, periodic observations at 2 ft. increments throughout the entire tank depth vary anywhere from 4° to 18° in zones from top to bottom. Our tanks are internally heated by circumferential coils extending from the bottom about half way up the side. The solids concentration varies from 4 to 25 per cent, with the highest value in the scum layer.

Mr. Bardet: There are days when we put 18,000 cu. ft. of raw sludge, or practically 10 per cent of the entire volume, into the digester. At no time has there been a drop in temperature over a 24-hr. period. If any trouble is experienced with the boiler during the winter months, the temperature may drop 1° to 1.5°.

Mr. Cerny: The average temperature drop depends on the ratio of the quantity of daily raw sludge addition to the volume of the digester. In the example just cited by Mr. Bardet, that drop would be almost 4°. However, the raw sludge would not be completely mixed with the entire contents of the tank, so that cold zones would exist where the temperature drop would be more than 4° average. These values are based on 200,000 cu. ft. of tank contents at 90°, and 18,000 cu. ft. per day of raw sludge at 50°. In a small tank, the application of cold raw sludge is for a short period and the effect is more pronounced.

Chairman Symons: The next topic is design of heating systems and related questions. The words "temperature coefficient," "heat exchange," and "transfer coefficient" have been used here interchangeably. Actually the term is "coefficient of heat transfer," and is expressed in Btu. per square foot per hour per degree difference in the temperature. A Btu. is a British termal unit, or the amount of heat required to raise the temperature of 1 lb. of water 1° F.

Mr. Velzy: Precise detail is not necessary in heat exchange problems in sewage treatment plants. For example, the thickness of the separating medium has an influence on the coefficient of heat transfer, but the effect is not great enough to be outside the errors of the original assumptions in the case of a sludge tank wall and roof.

Mr. Cerny: The subject of heat exchange is relatively new to most of us in this field and can become quite confusing if the terminology is not defined. In other discussions heat transfer rates have been quoted ranging all the way from 10 to 2,000 Btu. per sq. ft. per degree temperature difference. Obviously, not everyone was talking about the same thing.

The over-all coefficient of heat transfer can be defined as the rate at which heat is transferred from one medium to another per unit area of retaining wall, expressed as Btu. per sq. ft. per hour per Fahrenheit degree temperature difference. For tubes, the outside surface area generally is used.

Confusion often has resulted between this coefficient and the film coefficient of convection, which can be defined as the rate of heat transfer between retaining wall and fluid per degree temperature difference between the surface of the wall and the main body of the fluid. Factors affecting both these coefficients include diameter, material, and wall thickness of tubes; characteristics, velocities, and direction of flow of the liquids; and temperature range and difference of the liquids.

In designing a particular job, provision is made for addititonal Btu. demand. This represents the difference between the clean tube coefficient and the design coefficient, which involves a fouling factor that allows for deposition on both sides of the tube wall and depends on the physical and chemical characteristics of the liquids involved.

Check measurements on the units at Dayton, Ohio, after a year's operation, disclosed that the water temperature had to be increased 10° F. over the clean tube temperature to get the same output. That would presuppose cleaning of those units every 3 to 4 years and is an indication that the fouling factor used in the design is reasonable.

Mr. Fischer: A rapid way of figuring radiation loss is to take the sum of the areas of the tank walls, roof, and floor and allow a radiation loss of 6 Btu. per sq. ft. per hr. The resulting value of radiation loss is for the coldest 2 weeks in the year. This value should be added to the heat required to raise the sludge from 50° to 90° F., and the whole increased by a safety factor of 25 per cent.

Mr. Cerny: Another general method of computing digester radiation losses is based on correlation of observed temperature drops over a 24-hr. period for entire tank contents with the ratio between tank volume and wetted surface. This gives a mass temperature drop varying inversely with the size of the digester.

Chairman Symons: In two-stage digestion is heating of the second stage advisable or necessary?

Entire Panel: No!

Chairman Symons: How does the cost of an external heat exchanger system compare with internal heating coils as to installation and operation?

Mr. Fischer: That depends on the basis of comparison. A spiral heat exchanger would be about the same in first cost as standard internal coils for digesters about 30 to 40 ft. in diameter. The operating cost of any external heater is greater than that of internal coils, if corrosion is neglected, as there is a pumping cost to be considered with external exchangers.

Mr. Cerny: A mid-western plant was designed with heating coils and boiler. After bids were taken, the engineer permitted the contractor to substitute a combination heater and heat exchanger unit at no extra cost. He indicated the change effected a saving of between 10 and 15 per cent. That was a single-tank installation; in the larger plants having multiple digesters external heating has a definite advantage. In one plant, the exchangers for four large tanks are estimated to cost about the same as the heating coils for only one tank. Obviously, the cost of operation of external heat exchangers will be greater than that for internal heating coils, particularly if maintenarce and other factors are ignored.

Chairman Symons: With internal heating coils, at what heating water temperature will sludge cake on the coils?

Mr. Moore: Ordinarily, the inlet water temperature is seldom more than 140°, as a matter of safety. With higher temperatures there is a decided likelihood that caking will occur, especially above the thermophylic range.

Mr. Fischer: The temperature at which caking starts is indefinite. Sometimes caking takes place at low temperatures; sometimes it does not occur, even at high temperatures. After the thermophylic digestion tests at Jackson, Mich., it appeared that caking of the coils had occurred. When the tank was drained so the coils could be cleaned, it was found that gritty material piled up around the edges of the tank had practically covered the coils with gritty dead sludge, thus reducing the heat transfer. During the tests the water in the coils was heated as high as 200°. At Aurora, Ill., considerable caking occurred with heating water at 140°. Apparently, the incidence and amount of caking depends on the characteristics of the tank contents.

Mr. Cerny: The greatest trouble is deposition, as the coils will foul regardless of temperature. In addition, the transfer coefficient is so low that it takes a lot of fouling to reduce it appreciably.

Mr. Velzy: Conditions around a coil affect it more than does the heating water temperature. If the sludge is kept circulating, the water temperature can be higher without caking.

Chairman Symons: How can scum be kept warm, especially in winter?

Mr. Cerny: Insulating the top of the tank can help. Circulation of warm material so that it reaches that entire zone is also quite effective. Actually, efforts should be made toward prevention rather than cure.

Mr. Velzy: I'll confirm that. It is almost impossible to keep the scum layer warm in winter. The best cure is to use circulation or stirring that will actually keep the scum down and mixed with warm liquor.

Mr. Bardet: An electric belt around the tank was suggested at another discussion of this problem. However, because the conductivity of the scum is so poor, the belt would be ineffective. With 18-in. thick scum, the only solution was to submerge it or remove it. The best solution for wintertime scum troubles is to keep grease and scum out of the seals.

Chairman Symons: Is temporary heating worthwhile in starting a new digester?

Mr. Fischer: It is advisable never to start a digester in the wintertime. If, however, a digester must be started durirg the winter, the accumulated raw sludge should be transferred to the beds before digestion starts, as the tank will foam when the sludge starts to work. If the digester is started up in spring and an optimum pH is maintained, active digestion will begin without foaming.

Chairman Symons: Is periodic cleaning of an entire tank necessary, and if so, when?

Mr. Fischer: Emptying the digester at Jackson for the purpose of cleaning the heating coils was beneficial, as a tremendous volume of dead sludge was removed from the tank. The practice in the United States of using flat digester floors is poor design.

Mr. Moore: It is important to empty digesters periodically for inspection and cleaning. Speaking of flat bottoms, the only way to get grit from the edge of the tank to the sludge outlet is by the use of shovels and man power.

W. R. Schreiner, District Sanitary Engineer, State Dept. of Health, Glens Falls, N. Y.: At the Glens Falls plant sludge pumps had to be used to get the grit out of the flat digester bottom. With no suction line available they had to siphon it out.

Mr. Velzy: The comments on the slope of digester bottoms, particularly from the operating viewpoint, are interesting. From the construction standpoint, bottom slopes have been kept flat as a means of convenience in building. The bottom slopes should be steeper.

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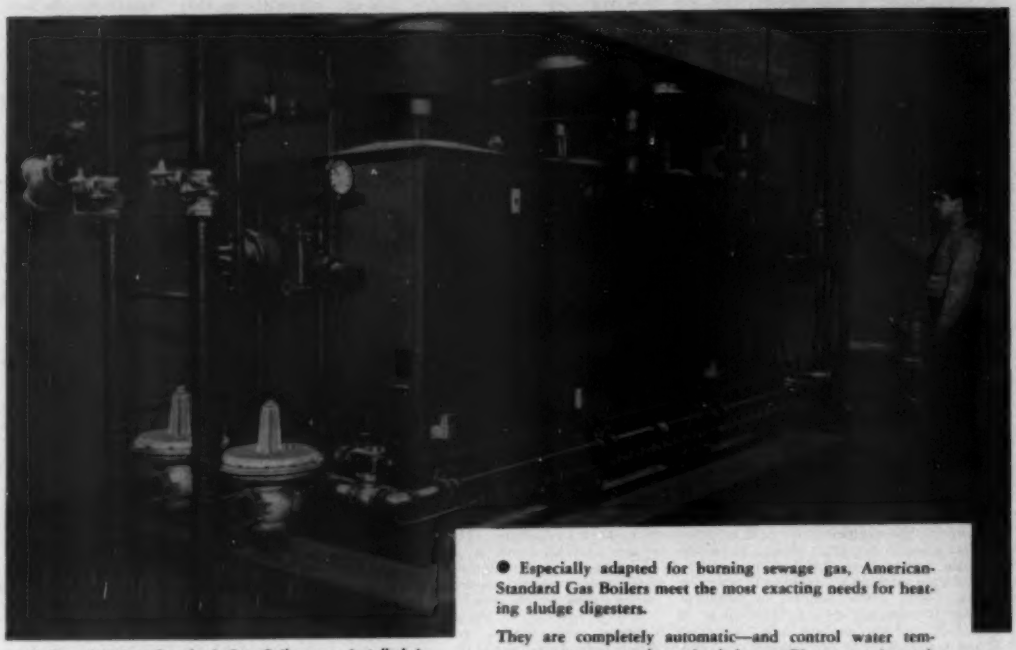

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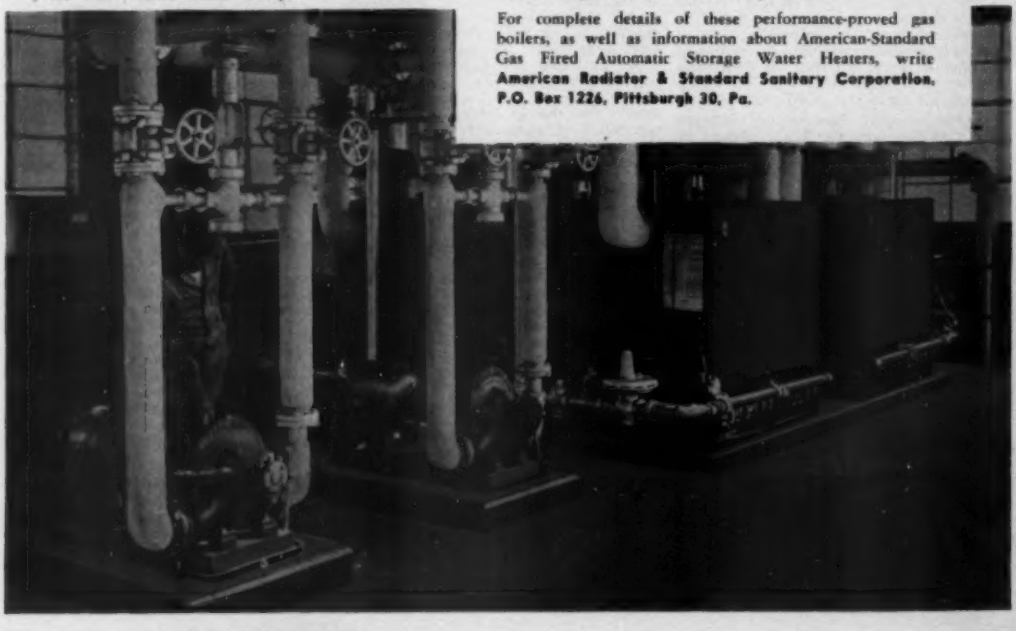

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	1-GA-4E	31,500		210	39,375	56	40½"	16	19¼"
	1-GA-5E	42,000		280	52,500	75	40½	16	22⅝
	1-GA-6E	52,500		350	65,600	94	40½	16	25⅞
	2-GA-4E			420	78,750	113	54⅝	16	19¼
	2-GA-5E	63,000		560	105,000	150	54⅝	16	22⅝
	2-GA-6E	84,000		700	131,250	188	55½	16	25⅞
	2-GA-7E	105,000		840	157,500	225	55⅞	16	28¼
	4-GA-8E	126,000		980	183,750	263	54	16	37⅛
	4-GA-9E	147,000		1,120	210,000	300	54½	16	40¾
	4-GA-11E	168,000		1,400	262,500	375	54⅞	16	46⅛
0-GS-4E		210,000			76,500	109	52¼	16	33¾
0-GS-5E		61,200	255		102,000	146	53	16	37⅛
0-GS-6E		81,600	340		127,500	182	53⅛	16	41⅝
	1-GW-4	102,000	425						
1-GS-4				600	180,000	258	57¾	19	25
1-GS-5	1-GW-5	144,000	600	800	240,000	343	59⅛	23	25
1-GS-6	1-GW-6	192,000	800	1,000	300,000	429	60¼	27	25
1-GS-7	1-GW-7	240,000	1,000	1,200	360,000	517	62⅝	31	25
1-GS-8	1-GW-8	288,000	1,200	1,400	420,000	600	62⅝	35	25
1-GS-9	1-GW-9	336,000	1,400	1,600	480,000	686	63¼	39	25
1-GS-10	1-GW-10	384,000	1,600	1,800	540,000	771	65	43	25
4-GS-6		432,000	1,800	2,000	600,000	857	65⅝	27	41½
4-GS-7	4-GW-6	480,000	2,000	2,400	720,000	1029	74	31	41½
4-GS-8	4-GW-7	576,000	2,400	2,800	840,000	1200	75	35	41½
4-GS-9	4-GW-8	672,000	2,800	3,200	960,000	1372	77	39	41½
4-GS-10	4-GW-9	768,000	3,200	3,600	1,080,000	1573	77¾	43	41½
4-GS-11	4-GW-10	864,000	3,600	4,000	1,200,000	1715	79½	47	41½
	4-GW-11	960,000	4,000	4,480	1,440,000	2060	80		41⅞
4-GS-13		1,152,000	4,800	5,120	1,680,000	2400	75	27	41½
4-GS-15	4-GW-13	1,344,000	5,600	5,760	1,920,000	2740	77	31	41½
4-GS-17	4-GW-15	1,536,000	6,400	6,400	2,160,000	3086	77¾	35	41½
4-GS-19	4-GW-17	1,728,000	7,200	7,680	2,400,000	3425	79½	39	41½
4-GS-21	4-GW-19	1,920,000	8,000	8,960	2,520,000	3600	80	43	41½
	4-GW-21	2,016,000	8,400	10,240	2,880,000	4120	77	47	41⅞
4-GS-22		2,304,000	9,600	11,520	3,240,000	4625	77¾	61½	41½
4-GS-25	4-GW-22	2,592,000	10,800	12,800	3,600,000	5145	79½	69⅛	41½
4-GS-28	4-GW-25	2,880,000	12,000	13,440	3,840,000	5480	80	77⅛	41½
4-GS-31	4-GW-28	3,072,000	12,800	15,360	4,320,000	6165	77¾	85⅛	41½
	4-GW-31	3,456,000	14,400	17,280	4,800,000	6850	79½	93¾	41½
4-GS-33		3,840,000	16,000	19,200			80	103½	41½
4-GS-37	4-GW-33			20,480			77¾	115½	41½
4-GS-41	4-GW-37			23,040			79½	127½	41½
	4-GW-41			25,600			80	139½	41½
							77¾	153¾	41½
							79½	169⅝	41½
							80	185¾	41½

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SLUDGE HEATING METHODS*

R. A. GREENE

Superintendent, Sewage Treatment, Jackson, Mich.

ALMOST continuous research has been going on in an effort to provide more adequate heating systems for separate sludge digesters since the first of these units was put in operation some 25 or 30 years ago. The tempo of this work has increased with the passing years because of the greater importance placed on this part of the treatment plant. Due to the increased utilization of the gas produced from the digestion process and the importance of temperature as one of the main factors affecting digestion, a method of heating has been sought that not only is adequate, but also provides maximum flexibility of operation.

The heat requirements which must be met by any type of heating system are composed of two main parts. First, and in practically all cases the largest, is the heat required to raise the incoming raw sludge from its natural temperature to the temperature desired in the digester. Second, is the heat lost through the external surfaces of the digestion tank. There are other factors which might affect the heat requirements to a minor degree, but it is believed that they would constitutea small fraction of the total.

The heat required to raise the temperature of the raw sludge to the temperature of the digestion tank is a straightforward calculation. The specific heat of the sludge is generally taken to be the same as for water. The heat required, in B.t.u., is equal to the product of the pounds of raw sludge and the temperature difference between the raw sludge and the digester temperature. The heat lost through the surface area of the digester is more difficult to state when attempting to apply a general formula applicable in all cases. It is a composite of several factors, and can be determined by the conductivity of sludge films inside the digesters, the conductivity of the material of which the tank is constructed, and the conductivity of the air or earth in contact with the outer surface of the digester. It appears, in general, that to raise the temperature of the raw sludge to the temperature of the digester would require 70 to 80 per cent of the total heat requirements, and that 20 to 30 per cent would be required to compensate for heat losses through the surface of the digestion tank where earth was banked around the outer walls of the tank.

Several methods of heating have been used in an attempt to meet the abovementioned heat requirements. The heating systems devised for this purpose have been tried not only as to their ability to meet the requirements demanded by the digestion process, but also as to the efficiency of the particular heating devices themselves. The sewage plant operator is interested, in most cases, in meeting the heat requirements of the digestion process with the lowest total amount of B.t.u. contained in the fuel being used. The operator is always interested in the flexibility of the heating system, as it is not regular routine operation which causes alarm, but those circumstances which are somewhat out of the ordinary. Another test which any heating system must pass is that of maintenance cost. Operators may still be inclined to look on the digester as an unwanted appurtenance, but they do realize the importance of the smooth functioning of a heating system, without undue maintenance cost, as a real help in the overall treatment process.

Heating Systems

Some of the heating systems which have been used are as follows:

(1) The passing of steam, generated in a boiler, directly into the digester in most cases requires softening of the boiler water supply. It also requires considerable attention, and for these and other reasons this method has never gained wide acceptance, although it is a very direct method of heating. If thermophilic digestion were the principal consideration, this method of heating would come in for greater consideration. In the experimental work on thermophilic digestion carried on at the Jackson, Mich., sewage treatment plant, ejection of steam directly into the digester was the most satisfactory method tried. About 75 per cent of the B.t.u. content of the gas burned in the boiler was transferred to the digester as heat.

(2) The ejector type heater hardly has been used enough to be considered, although it also was used at Jackson in connection with the thermophilic digestion experiments. This equipment consisted of an ejector through which sludge from the digester or raw sludge was circulated. The heating chamber was connected to the ejector and the heat from the burned gas, along with the hot gas fumes, were to be drawn into the digester by the velocity of the sludge passing through the ejector. The heating device proved to be very inefficient; the velocity of the sludge did not appear to be great enough to draw the heat generated by the burning gas into the digester.

(3) The method of preheating the raw sludge in a tank in which steam coils are inserted has been used to come extent. Sludge from the digester was also brought back into the preheating tank if necessary to keep the digester temperature at the desired level. This method never gained wide acceptance because: (a) some difficulty was encountered in pumping the hot raw sludge; (b) odors were caused by heating the raw sludge in an open tank; (c) sludge caked on the steam coils; and (d) excessive time and labor were consumed in heating the sludge due to the intermittent manner in which it was necessary in most plants to operate this type of heating system.

(4) The passing of raw or digesting sludge through steam has been used only slightly. It was found that the sludge would cake on the inside of the coils to such an extent that in a short time little heat would be transferred from the steam bath to the sludge.

(5) Heating coils mounted on the interior walls of the digester and through which hot water from a boiler is circulated have been more widely used than any other type of heating system. In most cases this has proved to be a good method of heating digesters. Nevertheless, the system does have a sufficient number of drawbacks to cause strenuous efforts to be made by sewage plant operators, and especially by equipment manufacturers, to devise a better method. In recent years, the wide acceptance of this heating method has been effectively challenged.

(6) The external type heating system, in which the sludge from the digester or the raw sludge is circulated, is challenging the heating coil method. The external type heater may be of the combined heater and heat exchanger type, or it may be a heat exchanger with a separate gas heater or boiler furnishing hot water. The last two methods are the most widely used, and for that reason more consideration is given herein to the advantages and disadvantages of both.

Coils vs. External Exchangers

Soon after separate sludge digestion was accepted as general practice, heating coils became widely accepted as the standard type heating system. This was apparently not because of the universal acclaim by sanitary engineers that it was good in all its aspects, although in the light of past experience it does appear correct to state that in the majority of heating coil installations the performance of these units has been satisfactory. Heating coil systems designed with a hot water boiler having proper controls and sufficient heating coil surface area inside the digester have given excellent service for many years with little maintenance. It should be pointed out, however, that lacking in this respect, experience has proved troubles to be in prospect when sufficient heating coil surface area is lacking. The same amount of heating coil surface area is not required for a digester containing 3 per cent sludge as for one containing a heavier sludge; that is, the more concentrated the contents of the digestion tank the less transfer of heat takes place per square foot of heating coil surface area when all other factors remain the same. Many digester heating systems were designed to heat the digester contents when the digesters were operated as single stage units. Preference of the plant operator for stage digestion left the primary digester carrying about 75 to 80 per cent of the heating load with insufficient heating coils. In those installations where such conditions exist, the temperature of the hot water from the boiler had been raised in an effort to meet the heat requirements. This has often resulted in progressive caking of sludge on the heating coils.

Caking on heating coils is one of the chief faults of this type heating system and places definite limitations on the flexibility of systems where it occurs. It has become almost axiomatic that the hot water entering heating coils should be kept below 140° F. to avoid forming this insulation on the coils. This, however, has not always been true. The hot water entering the coils at the Jackson sewage treatment plant during a considerable part of each of the past eight or ten years has been above 140° F. No appreciable caking on the coils has been experienced during this time. The heating coils in the plant have become embedded in sand, which

*Presented at 24th Annual Conference, Michigan Sewage Works Association; Traverse City, Mich.; Reprinted from Sew. Wks. Jour., Vol. 21, p. 968 by permission.

settled to such depths in the digestion tank as to form very good insulation around the coils. These same coils were used to aid in the heating of the primary digester during the experimental work on thermophilic digestion. Over this period, approximately three years, the hot water entering the coils was just below boiling. When inspected after completion of the experiments, very little scale or caking was present, although the coils were embedded in sand, the gradual decrease in the effectiveness of the coils showing that the deposition had occurred over a considerable period of time.

Although instances such as the one cited speak well for coils, it is known that sludge caking on heating coils has been and still is a nuisance. It is also known that heating coils do spring leaks for one reason or another. When trouble is encountered with coils, their location makes repairs on them a major task, not only because of the immediate damage, but also, in many instances, because of the effect on the entire operation of the treatment works. The digester must be emptied to make the repairs, leaving one-digester plants with no place to pump the raw sludge and cutting the digester capacity of the larger plants while the repairs are being made. The seriousness of the breakdown of coil heating systems in plants where they have occurred, and the fear of such breakdowns in other plants, has caused plant operators and designing engineers to look in the direction of the external heater as an answer to these problems. There are on the market today external heaters designed to meet the heat requirements of any size of digestion system. All operating parts are located outside the digester, where the necessary cleaning and repairs may be made. The external combined heater and heat exchanger is equipped with a circulating sludge pump, which circulates the digester contents through a water bath at controlled temperatures at the rate necessary to meet the heat requirements of the digester. This type heating system may be equipped to maintain the desired temperature in the digester by automatic operation. The external heat exchanger is also equipped with a circulating sludge pump that circulates the digester contents through the heat exchanger, where the sludge piping is surrounded by circulating hot water furnished by an outside source. This type may also be equipped with automatic operation controls. Either of the two methods of external heating may operate continuously or intermittently. Where the flow of hot water circulated and the flow of circulating sludge are both controlled there appears to be a greater transfer of heat per square foot of heating surface area than can be obtained from the combined heater and heat exchanger. The combined type is a more compact unit, and on single-digester installations would in most instances be less costly to install.

The heat transfer coefficient, which is the number of B.t.u. per sq. ft. per hr. per degree difference between the sludge and hot water, decreases rapidly as the concentration of the sludge increases. This applies to both the heating coil system and the external heating system. With coils, the heat transfer coefficient has ranged from 39 (digester contents approximating the concentration of supernatant liquor) to less than 10 (digester contents made up of thick sludge). The heat transfer coefficient is much higher for the external heater, a value of 240 having been attained by circulating clean water instead of sludge through the exchanger. This value is reduced rapidly as the per cent solids in the circulating sludge increases, but does not approach the low figure that results from the use of coils under the same conditions. The film of sludge, whether on the inside or outside of the heating surface, reduces the heat transferred.

There are some points in common between the external type heating system and the internal type represented by heating coils inside the digester. Both can be readily adapted to use jacket water from a gas engine as the source of hot water. Both, when equipped with the proper controls, can furnish heat desired in other parts of the plant. The inaccessibility of heating coils for maintenance purposes and the ready accessibility of all parts of the external heater appears to be the main point around which the preferences hinge. A comparison of the two types on some specific points is as follows:

(1) It is often stated that when the external type heating system is used, the cold sludge is raised to the desired temperature before introduction to the digester. These heaters are designed so that raw sludge may be passed through the heater before it reaches the digester. The raw sludge may also be mixed in any desired proportion with the seeded sludge in the digester. The mixing with seeded sludge may have definite advantages as an aid to more rapid digestion, but it seems unlikely that the temperature of the cold sludge would be raised appreciably. In the average plant, the time consumed in pumping raw sludge constitutes a small fraction of the entire day. However, heating of the raw sludge to the desired digester temperature constitutes approximately 75 per cent of the digester heat requirements. Nevertheless, external heaters are designed to operate continuously, or nearly so. This means that either the cold sludge would be pumped through the exchanger at such a rate that the temperature rise would be negligible, or the time consumed in pumping the cold raw sludge would be very great.

(2) Effective control of the digester temperature is sought by all plant operators, especially when full use of the existing digester capacity is needed. The external heater seems to have definite advantage at this point in that changes, which must be made on occasions, are more positive with the external heater because of the accessibility of all heating parts and controls.

(3) Recirculation of the digester contents speeds up digestion. This may be done by means of a circulating pump when using the internal heating coil system, but it is not likely that it will be done regularly. With the external type heater this recirculation is, of course, necessary. It does appear that if it is necessary to operate the external type heater continuously to maintain the desired temperature in a digester from which supernatant is to be drawn, it would have a harmful effect on the quality of the supernatant. The points of discharge of the circulated sludge can, however, be located to lessen this disturbance. One point of discharge is generally located in the scum layer usually present in all digesters. This should be especially advantageous in keeping the area warm and moist, and thereby digesting more of the solids in the scum layer than would otherwise be accomplished.

(4) Cost of operation is important. From the standpoint of power consumed in pumping, it appears that the advantage would be in favor of the heating coil system. Comparison of this method with the combined external heater and heat exchanger is basically one between the cost of pumping water and the cost of pumping sludge. The external heat exchanger system involves the cost of circulating both hot water and sludge. There is a very distinct possibility, however, that more effective use of the heating fuel may be attained with the external heater. Maintenance on a sludge pump runs higher than on a water pump. It also appears that there would be more time spent, on a daily basis, making adjustment on the external type heating system than on the internal heating coil system. However, this extra time is no doubt nullified by the greater effectiveness of the external units to do the job intended. When coils spring leaks or when they become caked or clogged, remedial measures are both costly and inconvenient.

At Dayton, Ohio, where an external heater of the combined heater and heat exchanger type has been in operation for approximately two years, Lloyd C. Huffman, plant superintendent, states that maintenance costs have been low. After one year in service, the fouling on the interior of the sludge pipes in the heater could be compensated for by raising the temperature of the water bath 10° F. A complete cleaning of the unit after the one year in service consumed 8 man-hours. This appears to be a very good record and speaks well for the effectiveness of the units.

(5) The rate which heat can be applied to the digester is of great importance on days when large amounts of cold raw sludge must enter the digester. The external type heater appears to be more flexible, in that heat may be more rapidly transferred to the digester without having any lasting effect on the effectiveness of the unit.

(6) It is no doubt more economical to install a heating coil system than the external type heating system in almost any size installation. This again comes back to the point of the accessibility of all parts of the external heater. If proper maintenance and control can more easily be made on the external type heating system, and more troublefree results obtained, this original cost could soon be offset.

It has been demonstrated in many installations that heating with coils is practicable and effective. It has also been demonstrated that coils are subject to caking with resultant loss of heat transfer. In recent years the combined external heater and heat exchangers, as well as boiler-fed external heat exchangers, have also demonstrated that this type of heating system is practicable and effective. It seems to be the answer to the weaknesses inherent in the heating coil system.

Acknowledgment

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TO LIME OR NOT TO LIME*

An Operators' Forum

CHAIRMAN Leroy W. Van Kleeck, Principal Sanitary Engineer, State Department of Health, Hartford, Conn.: The subject under discussion is the controversial one of liming of digesters and Imhoff tanks. One of the speakers, Mr. Schlenz, perhaps started us thinking along the lines of whether liming is needed or not in his historical statement of 1944 when he said that lime in any form or any amount had no place in a digester. A somewhat different viewpoint will be advanced by our first speaker, who believes in liming under certain conditions.

J. H. L. Giles, Senior Sanitary Engineer, State Department of Health, Hartford, Conn.: To lime or not to lime is a matter for each operator to decide on the basis of experience with his individual plant. In Connecticut, it has been the experience of many operators and representatives of the State Health Department that it is beneficial to add a few pounds of lime to the liquid content of a digester when it is being started up, in order to reduce an initial septicity which frequently develops in a tank during the first few weeks, whether it is heated or not.

It has generally been the experience of operators in Connecticut that for a heated tank of adequte capacity, no lime is needed after this first period of 3 or 4 weeks. A stabilized pH of 6.8 to 7.0 usually results in a digester kept at a temperature of 90° F., if it is of adequate capacity.

There are many sewage treatment plants in Connecticut that have had experiences which upon investigation and experimentation have resulted in the conclusion that periodic small additions of lime are necessary to get adequate digestion or to keep under control slow activities during the colder months for an unheated tank. We have also had two or three plants that have found it necessary to continue liming the year around in order to avoid the development of excessive accumulations of scum in unheated digesters.

The principal advice I would offer the operator is that no segregation of lime should be permitted in the bottom of the tank. Circulation of the bottom sludge with the incoming raw sludge is frequently helpful in avoiding segregation and permits regular testing of the pH or alkalinity of the digestion compartment. Overliming in one heated digester resulted in complete stoppage of digestion. On the other hand, the complete lack of lime in some tanks has resulted in very slow digestive action and frequently has resulted in excessive scum, septic conditions, and very poor supernatant.

Experience has indicated that in unheated separate sludge digestion tanks 50 lb. of lime per 1,000 population per week, added in small frequent doses, is not excessive, although at times even this amount is stopped for a period of two or three months during the winter in order to avoid foaming with the advent of warm weather. Generally, alkalinity below 1,000 and pH below 6 indicates the need for liming, whereas pH above 6.5 and alkalinity above 1,800 indicate that liming should be avoided, except as a very occasional application to stimulate action in the digester, which results in increased methane production.

Harry E. Schlenz, Vice-President, Pacific Flush Tank Co., Chicago, Ill.: When the statement was made in January of 1944 that "lime in any form or amount has no place in a digester" it was realized that this thought was contrary to the general opinion of others on the subject. In fact it was so contrary to my previous thoughts on the control of sludge digestion that it took a great deal of evidence obtained the difficult way to give rise to a statement that lime could do more harm than good in a digestion system.

In a pamphlet on the control of sludge digestion issued to operators in 1941 I was so firmly convinced of the importance of liming that the statement was included: "pH should be checked at regular intervals, and lime should be added, if necessary, to keep the pH from dropping below 6.8." I had held such thoughts since leaving the University of Illinois in 1927 after being well indoctrinated with the knowledge of the importance of pH in the control of sludge digestion, and that the mystical value of pH 7 was the guiding control, and lime should be added until that value was maintained.

Time will not permit reference in detail to the mass of data available to support this radical view on the subject, but a few operating experiences will serve to illustrate the reason for present views against liming as a control measure.

In 1942-43 we were asked to attempt correction of a serious situation at one of the large naval training centers, where for 10½ months raw solids had been added to a digester system without any resultant digestion. During that period, about 9 tons of lime had been added to one of two 65-ft. diameter digesters, with the pH being raised from 5.0 to only 5.4. An inventory of the tank contents revealed that the upper ⅔ had a pH of 5.0 and the lower ⅓ a pH of 7.0, but the tank was dormant.

Still of the opinion that the liming procedure was not entirely wrong, it was felt that an excess of lime had been added. The first procedure, therefore, was to draw off as much of the bottom material as could be conveniently disposed of. A careful check of the operating records showed that the temperature had been maintained at the optimum of 90° to 100° F. during the last 2½ months of the 10½-month period so that except for the low pH proper conditions for effective digestion appeared to be present.

A continuous and large-volume recirculation of the tank contents was started, although this recirculation was restricted to the upper half of the tank. In 10 or 15 days, gas production started and the tank started to foam, at which time the gas production reached a peak of 4 to 5 times a normally anticipated rate.

It was found, however, that recirculation of material from the bottom of the tank to the top stopped gas production almost immediately and that the foaming action also was retarded. This indicated that recirculation of the sludge still containing some lime would show a retarding action on the rate of digestion.

The next example of the effect of lime was brought out in connection with the digestion tank installation handling solids from a malt house waste at Jefferson Junction, Wis. Because of the type of waste, the two digesters in the system were started very carefully, with the tank contents heated to an optimum point. The raw solids were then added, starting with a light load and increasing to the maximum load. The pH of the tank contents was initially 7.0, but in 10 days the pH had dropped to 6.56. Despite the experience on the project previously reported, it was decided to keep the pH at 7.0 and lime was added carefully, using approximately 100 lb. per day with a day of rest between subsequent additions. The 100 lb. of lime represented approximately 600 ppm. of actual lime. In seven days, with about 3,500 ppm. of lime having been added, the pH had risen but slightly to 6.6.

Due to the slight rise in pH as contrasted to the fairly large quantity of lime added, it was decided that no further additions of lime should be made. In another 7 days, with careful recirculation of the upper portion of the primary digestion tank in the two-tank system, gas production had started and was steadily increasing. However, it was again noted that with recirculation from the bottom of the tank gas production was sharply reduced. It should be noted that the lime accumulation in the tank had not been removed. During the next month the rate of digestion, with recirculation of the upper portion of the tank only, indicated that digestion was well established, with the tank taking the full raw solids load.

About that time a visitor to the plant who saw the records indicating that the pH of the tank contents was fairly low, insisted that the operator correct this condition by adding lime. The operator disregarded previous instructions and added lime, although the records do not show the quantity added. The result was immediate cessation of digestion in that tank. It was impossible to start the digestion again, with the result that all feed to the primary digester was stopped and the raw solids were diverted into the tank used for secondary digestion, which had never been contaminated with lime additions. To this day the secondary digester as shown on the plans is being used as a primary digester, the original primary digester being finally brought back into action without the use of lime.

A number of other examples and operating records could be mentioned if time permitted, but some reference should be made to the digestion installation at Crystal Lake, Ill., handling a yeast plant waste. This plant was designed and operated with only an allowance of 3 to 4 days for the full two-stage digestion. When the operating schedules were set up, instructions were given to omit the practice of taking pH readings. This digester system has been in successful operation since 1945 and there has never been a pH reading taken on the digester contents; thus, there has never been any occasion for the operator to add lime to correct for a low pH.

In conclusion, it might be suggested that it does not appear possible to establish good digestion conditions merely by correcting the pH of the tank contents. Instead, the pH is the result of having established good digestion conditions. It is much more important to start the digestion by providing an optimum temperature of the tank contents from the day that the first raw solids

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are added, and start adding raw solids at a rate that will prevent the building up of acid conditions, increasing the rate of raw solids addition as the tank is able to assimilate the load.

W. W. Matthews, Superintendent, Gary (Ind.) Sanitary District: It appears that Mr. Schlenz takes the stand that lime is not used simply because it has been brought in by the truckload and dumped indiscriminately into a tank. Each case requires careful thought. I have thought that operators, except perhaps the very newest ones, were sufficiently informed that they didn't think it necessary to try to control pH with lime.

If I were asked the average pH of our five digesters right now, I couldn't tell. The transfers are sampled each day and the pH is recorded in the laboratory book, but unless something is obviously wrong nobody pays any attention to them, because it is well known that at different plants digesters stabilize at different pH values.

As I remember, the digesters at Decatur, Ill., stabilize at about 6.5. I know ours are somewhere between 6.9 and 7.1. I have never tried to control pH or foaming with lime—let it run over the bank if it will, if it doesn't bother your plant site—it will correct itself.

We use lime for a different purpose—to increase gas production. How that is accomplished I frankly don't know. We are troubled with oil. We get soluble cutting oils from one plant and the effect of such oils is insidious. We can't tell exactly when the soluble oil is coming in, and it builds up in the digesters. My theory on it is this: We know that oil will inhibit digestion; and when a tank falls out of line in gas production, where the total averages 35,000 to 40,000 cu. ft. per day for the five tanks, the outside operators notice it when they take their reading. Whenever everything else is normal as regards the sludge pumpage—no storms or anything unusual occuring—the corrective measure is to put 100 lb. of lime into a digester holding 1,300,000 gal. of sludge mixture. The chemical effect of that much lime on over 8,000,000 lb. of mixture is negligible.

It is thought that the action is a physical one, merely absorbing some of the oil and stimulating digestion in the tank. This follows from the observation that one of the best ways of drying up a lot of oil spilled on a concrete floor is to sprinkle it with lime.

I agree, however, that use of excess lime is definitely bad; it is like any other medicine and should be used as the doctor prescribes.

Mr. Schlenz: I do not feel that Gary has any real digester problems with its large digestion capacity (8 cu. ft. per capita). My thinking is directed toward those plants having less than 1 cu. ft. per capita.

Probably the lime added to the Gary digesters combines with the CO_2 in the gas to form $CaCO_3$ which soaks up some of the oil. However, the addition of 100 lb. of lime to 8,000,000 lb. of tank contents can hardly be considered liming. In the case I mentioned, the 100-lb. additions of lime were made to a 15-ft. digester, without changing the pH.

Mr. Giles: The description of recirculation from the bottom half of a digester indicates obvious over-liming of the tank. We had the same experience in an industrial waste treatment plant with three digesters. After the plant had been in operation a year there was no solid in the tank, only scum. The plant was handling a wool fibre waste with a 600-gcd. flow (5 mgd. for 8,000 population) and with absolutely no digestion.

We added, finally, a whole ton of lime to that small digester in 100-lb. batches. By that time the pH of the whole tank was over 8.4 and digestion had ceased. The scum went to the bottom, and it was thought that possibly, even though the digestion had been killed, some good had been done. Then came the stench; I have never seen or smelled anything quite so septic. A little more sludge was added and almost overnight the tank contents turned upside-down; all the dead sludge came to the top, and nothing we tried did any good. To this day it is impossible to control it; the scum is just broken up and taken off.

At one institution with a population of 1,000, an Imhoff tank was started up very carefully, with good digestion resulting. When some new buildings were built clay soil got into the sewer through the new connections. This practically solidified that whole tank. Intensive recirculation was necessary to work out the clay. After the tank was operating again, 20 to 25 lb. of lime have been very carefully added at a time, and recirculated so there would be no accumulation of lime. The tank has worked pretty well.

Two or three years ago the plant was enlarged, including a second Imhoff tank having 50 per cent more sludge capacity than the original one. The new tank was not limed for 1½ years, but we still didn't get what I consider good digestion. There was very little action. When a new operator came to the plant, he had been accustomed to liming and the other tank was being limed, so he added lime—a total of 400 lb. in two months. The lime was added, because the sludge was rather bad, but when 1½ ft. was drawn onto the drying bed, it was in good condition.

The general experience has been that a little liming, well applied, can help.

E. A. Locke, Operator, Sewage Treatment Plant, Hartford, Conn.: At Hartford, the plant is shut down for two months in the spring due to the high level of the river. There are 4 digesters, which contain a lot of well-digested sludge when the plant is opened up. Also, we probably have to take up about the full load of raw sludge.

It was found that raw sludge pumping lowered the pH. It was allowed to drop to about 6.8 or thereabouts before 100 lb. of lime was added. As the pH continued to droo to 6.6 it was thought that something had to be done, so a dozen bags of lime were added in each tank. This not only raised the pH. but also increased gas production. A little lime was added each day until the pH was around 6.8 or 6.9 and gas production was nearly normal. Judicious liming is now our standard practice in starting up again after a shut-down. Once the proper nH is attained liming is stopped.

Mr. Schlenz: It is possible that if Mr. Locke had just left the digester alone, the digestion would have come back. To support this contention I might refer to additional operating records for the Jefferson Junction, Wis., plant previously referred to. About 9 months after a good digestion action had been obtained in the digester originally designated as a secondary and which had been pressed into service as the primary tank to receive raw solids, there was a period of about 6 days when the pH had dropped off from the normal 7.2 to 6.3. The operating records indicate that there had not been any change in the operating procedures, no lime had been added, the temperature had been kept at an optimum value, and recirculation of the upper portion of the tank contents had been practiced in the usual manner. Without any special changes in operation, after a further 10-day period the pH returned to a normal of 7.0, but the gas production increased to about three times the normal anticipated rate. It appears that something in the digester action caused raw solids to be stored up, with a resultant reduction in the pH, but that without any special manipulation on the part of the operator the digestion started again and went beyond a normal rate.

L. J. Fontenelli, Supervising Engineer, Rahway Valley (N. J.) Joint Meeting: I'd like to ask Mr. Schlenz if, during the period when the pH dropped rapidly, loading of fresh solids was continued.

Mr. Schlenz: According to the records, solids were being added at that particular time and were actually 20 to 25 per cent more than the normal loading for the preceding period, and continued at the high value from that period throughout the balance of the recorded data.

Possibly due to the increase in the rate of raw feed, the digester had to adjust itself to the change. The volatile acids increased to a high value with the heavier load, but for some reason or other the tank adjusted itself properly to that heavier load. As the heavy load went in the volatile acids went up and the pH went down. Then the tank gradually adjusted itself, without adding anything other than the raw solids.

M. M. Gibbons, Superintendent, Board of Water Commissioners, Rahway, N. J.: If a plant is operating 24 hr. per day on a fixed digestion tank capacity, it is very nice to say, theoretically, that the digesters should be rested. However, something must be done with the fresh solids. Rahway, of course, is confronted with lack of digestion capacity, so that it is imperative to keep feeding just as much of the fresh solids as possible.

At the Rahway plant we try to maintain a pH between 7.1 and 7.2. It has been noticed time and time again that, during conditions of over-loading, the pH will drop very slowly to about 7.0, and then will decrease within the course of 2 or 3 days to 5.3 where it seems to become stabilized. If a little lime is added when the pH is dropping between 7.1 and 7.0, the solution can be buffered and the pH held in that range. If, however, the pH gets below 7.0, tons and tons of lime are needed to bring it back up to where it should be.

Perhaps there is a different type of water in New Jersey; but, from experience, we have been able to continue sustained loadings of about 20 per cent more with lime than without lime. For the past three years, our solids loading has been about 5½ lb. of solids per cubic foot per month. With that, we have destroyed 50 per cent of the volatile material in the primary tank, and an additional 10 per cent in the secondary.

It has been our experience that without lime our capacity is decreased about 20 per cent. It seems to be cheaper to add a little lime (in our case about 15 per cent of lime on the dry basis of solids in the tank) than to provide the necessary additional capacity.

K. E. Foote, Superintendent of Disposal Plants, New Haven, Conn.: When the New Haven digesters were put in operation, the first one was fairly dormant for several months. The supernatant was foul, and the pH was around 5. No lime was added. As a result of experiments with a small digester in the laboratory, lime was added to the second digester when it was started. That digester produced gas in about 28 days, whereas the first tank had run several months. There were even articles in the newspapers about not being able to get the gas production going at the sewage plant.

The digesters were designed on the basis of 1 cu. ft. per capita, with a population of 87,000.

SLUDGE DISPOSAL VS. SLUDGE UTILIZATION*

An Operators' Forum

CHAIRMAN Le Roy W. Van Kleeck, Principal Sanitary Engineer, State Department of Health, Hartford, Conn.:—Many factors are involved in the question of whether to dispose of sludge or to utilize it. There is even considerable overlap in the two fields of thought if the word "utilization" is interpreted differently—that is, does utilization include production of sludge gas; or does utilization begin only after the treatment plant has completely finished with the sludge? Such questions, however, will be left to the two well-qualified speakers who open the discussion of this subject.

W. Rudolfs, Chairman, Dept. of Sanitation, N. J. Agricultural Experiment Station, Rutgers University:—Some 40 years ago Raymond Wells of Homer, N. Y., wrote a paper on the "Economic Values of Sewage and Sewage Sludge." His thesis was that sewage and sludge should be utilized for their fertilizing values. He felt that the problem of sludge disposition was not impossible, but difficult, requiring the cooperation of chemists, engineers, business men, and politicians. In many respects we are at the same place today. Cooperation and good-will are necessary.

There are, at present, primarily two schools of thought: (1) destroy the filthy mess, and (2) conserve all possible to restore worn out soils and keep food plant production at a high level. The destroyers say that their methods are the cheapest and most hygienic, cause the least difficulties, and prevent nuisances. The conservationists present arguments based on the value of sludge for soil building and stimulation of plant growth. I happen to belong to the conservationists, believing that, particularly for the smaller sewage plants, sludge utilization may be less costly than destruction. After all, utilization of sewage and sewage sludge is fundamental to the earliest methods of disposal (irrigation, sewage farming) and there is nothing that has changed this basic principle. During the years many and varied attempts have been made (composting, sludge digestion, sterilization, etc.) to reduce or prevent nuisances and possible dangers attendant on the utilization of human wastes.

In respect to public health dangers, there seems to be a good deal of misapprehension. Experiments made during the last two years, with vegetables grown in polluted soil and the spraying of *E. coli* cultures and feces on vegetables, show that the organisms are rapidly killed under natural conditions and the numbers of organisms found on growing tomatoes, even sprayed with raw sewage or feces, are at harvest time not greater than those grown in unpolluted soil, provided the spraying was stopped about a month before the tomatoes were picked. It is not a usual practice in this country to apply raw sewage, nightsoil, or raw sludge to the vegetables.

The use of sewage for irrigation, sludge for soil building, and, more recently, industrial use of effluents, is in effect nothing else than what has been practiced for many years. In addition to the use of sludge as fertilizer or fertilizer base, the utilization of gas and recovery of by-products, particularly from unusual or industrial sewages—such as grease and soap (Bradford, England), methyl alcohol and formaldehyde from gas (Johannesburg, South Africa), and alcohol and acetone (Japan)—indicates the possibilities of conservation on a broader scale. However, perusal of these possibilities would lead into longer discussion than is warranted here. Our thesis is: Utilize wherever possible, rather than destroy.

R. W. Rowen, Vice-President, Nichols Engineering and Research Corp., New York, N. Y.:—Obviously, I am biased in favor of heat drying or incineration of sludge as compared with any other methods of disposal. However, this leaning towards incineration is based on a sincere belief that it is the most satisfactory method of sewage sludge disposal. It certainly is the most sanitary, in that the end products are CO_2, H_2O, the nitrogen gases, and inert mineral ash. No other method of sludge treatment converts it to a state where it is absolutely harmless forevermore.

Sludge drying or incineration offers some very interesting possibilities that have not been fully exploited, particularly in the simplification of plant operation and design. For example, Milwaukee, Wis., has been incinerating grit and screenings without the addition of sludge for more than 10 years, whereas Detroit, Mich., burns its screenings, grit, and skimmings along with its filtered sludge. This method of handling has eliminated the cost of plant construction and operation, as well as the nuisance, of disposal of these other end products of sewage treatment. The fuel value contained in grit and screenings is sufficient to evaporate the water present and deodorize the gases. Burning is preferable to burial, and no washing or grinding is necessary.

It should be pointed out that immense simplification and savings in plant design and operation can be accomplished by the elimination of digestion. In many plants, shortage of digestion capacity has been relieved by incineration of vacuum filtered raw sludge to take the overload. In fact, about 70 per cent of all types of sludge incineration plants are handling raw-sludge filter cake.

Few cities incinerate sludge (either as filter cake or from a drying bed) along with garbage and refuse in hand-stoked furnaces. The operation, in general, is quite unsatisfactory, as it is difficult to break up the sludge mass for effective combustion.

An incinerator plant handling both refuse and sludge must be located close to the sewage plant. This is not always desirable from the refuse collection viewpoint, as the sewage treatment plant takes precedence as to location. The flash dryer or multiple-hearth types are finding increasing favor in this service, as they utilize the waste heat from refuse burning to dry the sludge, which is then burned with the refuse.

Another method can be used for combined incineration. The operation consists of grinding garbage and discharging it directly into a multiple-hearth incinerator along with sludge, or, as at Ashland, Ohio, burning ground garbage during the day and sewage sludge at night. Still another plant mixes the ground garbage with the sludge, vacuum filters the combination, and burns the resulting cake.

The third general class of incinerators is that in common use for drying and incinerating sewage sludge alone or in combination with grit and screenings. In the flash-dryer type, the filter cake is mixed with a portion of return dry sludge from the process, dried to about 35 per cent moisture, and discharged to the flash dryer, where it is reduced to about 10 per cent moisture. A part is returned for mixing with the new filter cake, the balance being finished as fertilizer or used as fuel in the furnace.

Another in the same class is the multiple-hearth type, in which drying takes place on the upper hearths and burning on the lower ones. When operated as a dryer, the gas flow in the furnace is reversed (top to bottom) with burning on the top hearth only, to avoid overheating or scorching the material being dried.

Incineration is complete disposal, is unquestionably sanitary, is economical, and is dependable, regardless of weather conditions.

Dr. Rudolfs:—There seems to be considerable misapprehension with respect to the so-called "sanitary" conditions involved in sludge utilization. Putting sludge on land has been considered a somewhat dangerous proposition. However, during the last two years considerable experimental work has been devoted to finding out how dangerous it really is, through the medium of applying to the land raw sludge, digested sludge, horse manure, and artificial fertilizers. Vegetables—specifically, tomatoes and spinach—grown in the supposedly polluted soils show no greater numbers of coliform organisms than do those grown in the artificially fertilized soils. Even after cultures of sewage solids are applied directly to tomatoes, if a few days is allowed before re-testing, the number of coliform organisms is no greater than that ordinarily found on tomatoes as marketed. Fresh feces put on vegetables completely disappeared after 3 days. With the amount of sunlight ordinarily received by the vegetables in the field the danger is very slight.

As to barging sludge to sea; aside from the cost it is a good scheme. It supplies an enormous amount of fish food, both directly and by fertilizing of sea plants. This in turn helps one of the great natural resources of any country, its fishing industry.

W. B. Walraven, Engineer, Springfield (Ill.) Sanitary Dist.:—We have no trouble in getting rid of all the sludge produced from a sanitary district serving about 110,000 people. During the summer private individuals owning two front-end loaders truck the sludge away. They deliver it as much as 12 to 15 miles. Consequently, its disposal costs nothing. Of course, such conditions may not prevail in other communities, but farmers want for their soil the additional humus contained in the digested sludge.

Beginning in 1932, I suggested that the digesting of sewage solids could be made to pay for itself by developing the utilization of sludge gas in gas engines. A crude yardstick set up then still holds good today—2 hp. can be developed per 1,000 population contributing to almost any treatment plant incorporating digestion. Digestion of sewage solids has not only given the farmers of our area an economical humus material, but also has averaged us somewhere between $10,000 and $12,000 annually since 1932 in reduced power costs.

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SLUDGE DEWATERING AND DISPOSAL*

By SAMUEL I. ZACK

Chief Sanitary Engineer, Gannett, Fleming, Corddry, and Carpenter, Inc., Harrisburg, Pa.

DISPOSAL of solids removed as sludge from sewage by primary and secondary sedimentation is the difficult and costly part of sewage treatment. Sludge thus removed varies in quantity depending on the method of treatment, is composed of a large percentage of putrescible organic solids, and is high in moisture content.

Sewage sludge is highly putrescible and, unless properly processed for disposal, is the principal potential nuisance encountered in the treatment of sewage. Unless disposed of, sludge can also be a nuisance from the standpoint of accumulation, even though properly processed. The purpose of processing and disposal, therefore, is to render the sludge unobjectionable and to get rid of it to avoid excessive accumulations.

Sludge from Sedimentation Tanks

Data on the amounts of sludge per capita per day and the percentage of solids and organic content are presented in Table I. The figures vary over a considerable range; in general, however, organic content and per cent solids are higher and sludge produced per capita is lower for primary settled sludge than for activated sludge with primary and secondary settling.

Concentration

After removal from sedimentation or digestion tanks, sludge can be concentrated in separate tanks to reduce the water content, to conserve digester capacity, and to facilitate dewatering on vacuum filters. Concentration of sludge (1) has been accomplished by separate thickening tanks, reductions in volume of sludge of 75 to 88 per cent having been obtained at Baltimore, Md., by their use. Unthickened sludge has a solids content of 0.9 to 1.1 per cent, and thickened sludge has a solids content of 1.4 to 2.1 per cent. Time is an important element in concentrating sludge. Primary settling tank sludges can be thickened to 6 to 8 per cent solids content by holding in settling tank sludge hoppers or in separate concentration tanks. Chemically precipitated sludges can be thickened to about 8 per cent solids content.

Donaldson reports that activated sludge ranging in solids content from 0.4 to 0.5 per cent was concentrated to 1.35 to 3.48 per cent solids by storage. Solids content of 5.94 per cent in digested sludge was increased to 7.94 per cent by storage.

The solids content in sludge is increased from 8.03 per cent to 9.09 per cent by thickening at the Minneapolis-St. Paul (Minn.) Sanitary District (2), with a corresponding reduction of 27 per cent in the volume of sludge going to the vacuum filters.

Excess activated sludge was thickened in concentration tanks from a solids content of 2.54 per cent to 4.05 per cent during the last half of 1947 at the Southerly plant in Cleveland, Ohio (3).

Sludge was thickened by storage to reduce the volume for barging to sea at the Elizabeth (N. J.) Joint Meeting plant. In 1944, the raw sludge had a solids content of 5.4 per cent before storage and a solids content of 8.2 per cent after storage. The reduction in volume by concentration amounted to about 45 per cent.

Some success has been reported in thickening sludge by the use of chemicals, both for precipitation and flotation. The flotation method, using alum, has been in use at Plainfield, N. J.

Concentration of sludge reduces the digestion capacity required and makes it possible to operate vacuum filters at higher rates, based on the amount of dry solids that can be dewatered per square foot per hour. It also reduces the volume that has to be barged where sea disposal is employed.

Digestion

The most common method of processing sludge is by digestion of the organic solids and drying the digested sludge on sand beds. Digestion is accomplished in Imhoff tanks, or in covered heated or unheated digesters. The collection and use of gas for fuel or power generation is incidental to the digestion of the sludge.

Data on sludge removed from digestion tanks are presented in Table II. Where digestion capacity is adequate, digested sludge has a higher solids content than raw sludge removed from primary sedimentation tanks. It has a much lower volatile content than raw sludge, and this figure varies in accordance with the amount of digestion accomplished. The volume of sludge to be handled is reduced 35 to 50 per cent by digestion.

Drying Beds

Either open or glass covered sand beds are utilized for drying sludge. Open beds have been used generally at the smaller treatment plants, and for the larger plants located on isolated sites of ample area, or in warm, dry climates.

Glass covered beds cost more per square foot, but more sludge can be dried on properly designed covered beds. Consequently, the drying bed area required is from 30 to 50 per cent less than for open beds. In order to hold costs in line with financing, construction of glass enclosures has been deferred on several recent projects until growth in population catches up with design capacity.

Digested sludge from Imhoff tanks at the West Side plant of the Sanitary District of Chicago is dried on open sand beds, then removed from the beds and loaded into cars by means of a mechanical bed cleaner and loader. Sludge removed from the sand beds is suitable for fertilizer, soil building, or land fill.

Some typical data on sludge removed from drying beds are given in Table III. Operating reports by municipalities do not provide much information on sludge removed from drying beds. The data shown indicate that the moisture content is from 50 to 68 per cent in sludge taken off the beds.

Mechanical Dewatering

In the past 15 years there has been a definite trend by the larger municipalities

TABLE I

Sludge Removed from Sedimentation Tanks

Location	Year[1]	Sludge Removed		Dry Solids		Org. Matter in Dry Solids (%)
		(g.c.d.)	(lb./cap./day)	(lb./cap./day)	(%)	
(a) Primary Settled						
Grand Rapids, Mich.	1946-47	0.34	2.9	0.12	5.6	70.2
Hartford, Conn.	1948	0.23	2.0	0.13	6.7	71.2
Minneapolis-St. Paul Sanitary District	1947	0.40	3.4	0.27	8.0	68.9
Racine, Wis.	1946	0.25	2.1	0.15	7.2	67.0
Buffalo, N. Y.	1945-46	0.19	1.6	0.12	7.2	68.5
Dist. of Columbia[2]	1947	0.13	1.1	0.09	8.2	64.9
San Francisco, Calif. Richmond Sunset	1944-45	0.23	1.9	0.08	4.3	84.1
Frederick, Md.	1948	0.38	3.2	0.16	5.0	—
(b) Chemical Precipitation						
Wilmington, Ohio[3]	1940	0.41	3.5	0.32	3.7	65.0
Lebanon, Ohio[3]	1940	0.89	7.6	0.89	9.6	26.9
(c) Activated Sludge with Primary and Secondary Settling						
Springfield, Ill.	1942	0.65	5.5	0.22	4.1	57.2
Jackson, Mich.	1947-48	0.54	4.6	0.25	5.3	59.0
Ann Arbor, Mich.	1947	0.83	7.0	0.19	2.8	76.9
Cleveland, Ohio Easterly	1947	0.73	6.2	0.24	3.8	64.0
New Britain, Conn.[4]	1944	0.27	2.3	0.17	7.5	—
Belleville, Ill.[3]	1944-45	0.62	5.3	0.17	3.3	69.0
Marion, Ind.	1948	0.65	5.5	0.29	5.2	61.0

[1] Annual report.
[2] Based on population equivalent.
[3] Report on operating tests, dated June 16, 1941, Ohio Department of Health.
[4] Guggenheim process.

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TABLE II

Sludge Removed from Digestion Tanks

Location	Year[1]	Sludge Removed		Dry Solids		Org. Matter in Dry Solids (%)
		(g.c.d.)	(lb./cap./day)	(lb./cap./day)	(%)	
(a) Primary Settled and Digested						
Grand Rapids, Mich.	1946–47	0.19	1.81	0.078	5.0	60.2
Hartford, Conn.	1948	0.12	1.01	0.050	4.9	50.7
Buffalo, N. Y.	1947–48	0.07	0.60	0.008	11.1	60.0
Dist. of Columbia[2]	1947–48	0.050	0.50	0.040	8.0	45.9
Racine, Wis.	1946	0.045	0.38	0.033	8.7	48.0
San Francisco, Calif. Richmond Sunset	1944–45	0.19	1.60	0.028	1.7	68.1
(b) Activated Sludge with Primary and Secondary Settling						
Jackson, Mich.	1947–48	0.31	2.60	0.18	6.9	45.0
Springfield, Ill.	1942	0.075	0.64	0.07	5.9	40.9
Ann Arbor, Mich	1947	0.39	3.25	0.04	1.3	65.3
Marion, Ind.[3]	1948	0.41	4.20	0.18	4.2	49.7
(c) Trickling Filter with Primary and Secondary Settling						
Elgin, Ill.	1945–46	—	—	—	3.7[4,5]	64.3[4,5]
					4.2[4,5]	60.2[4,5]
Galesburg, Ill.	1947	—	—	—	7.8[5]	43.1[5]
Worcester, Mass.	1944	0.28[4]	2.34[4]	0.17[4]	7.4[4]	45.9[4]
		0.09[5]	0.80[5]	0.03[5]	3.5[5]	47.3[5]

[1] Annual report.
[2] Based on population equivalent.
[3] Sludge digested with garbage and whey.
[4] Imhoff tank sludge.
[5] Digester sludge.
[6] Secondary settling tank sludge.

toward mechanical dewatering of sludge on vacuum filters. Various types of bag, plate, and frame filter presses have been operated in this country, but have not acquired popularity due to the labor required for operation and for removal of press cake. Centrifuges have not received general acceptance because of the presence of fine solids in supernatant liquor.

Except for the very small plants, the first cost of a vacuum filter installation is less than for drying beds. However, due to operating costs and the cost of chemicals for conditioning sludge, it is not economical to use vacuum filters for contributory populations less than 25,000 to 50,000. However, under some circumstances (such as critical plant site or presence of certain industrial wastes) it is feasible and desirable even for the smaller communities to use vacuum filters instead of drying beds, even though costs may be higher.

Vacuum filters are being used to dewater undigested and digested sludge taken out of sewage in primary treatment by plain sedimentation and chemical precipitation processes, and in secondary treatment by rock filters or activated sludge aeration, in each case followed by final sedimentation.

Normal practice is to utilize lime and ferric chloride for conditioning raw sludge from primary treatment, or undigested sludge from any treatment process preparatory to dewatering by vacuum filters. Ferric chloride alone is a suitable sludge conditioner for raw sludge produced by the activated sludge process, provided the amount of primary settled sludge removed is less than the amount of secondary settled sludge. The quantity of lime and ferric chloride required for conditioning digested sludge is very high. If digested sludge is elutriated or washed with 3 to 5 volumes of water per volume of sludge, it can be conditioned quite economically with ferric chloride alone.

Ferric sulfate and ferrous sulfate have been tried as sludge conditioners, but without a great deal of success. Alum has been used with some measure of success at Springfield, Mass. (4), on digested primary sludge after elutriation when ferric chloride was hard to get.

The filter cake produced from raw or undigested primary, chemically precipitated sludge or digested sludge from secondary treatment has a moisture content ranging from 60 to 75 per cent. A mixture of undigested settled primary and activated sludge can be dewatered to 75 to 80 per cent moisture, and settled activated sludge to 80 or 85 per cent moisture.

Vacuum filter cake from digested sludge can be used for land fill, soil building, or fertilizer, about the same way as digested sludge from sand drying beds. Whereas sludge from sand beds has to be handled manually or by a rather complicated mechanical sludge bed cleaner and loader, filter cake is dumped onto a belt, which can be made to discharge to a pile, directly into a truck, or through a storage hopper.

Undigested sludge filter cake has been discharged to an isolated dump, especially if heavily dosed with lime. However, such disposal is always a potential nuisance and hazard, aesthetically at least.

Data on sludge dewatered on vacuum filters are presented in Table IV. Table V gives the wet filter cake and dry solids in wet filter cake, expressed as pounds per capita per day, for various vacuum filter installations. It is obvious, from the data presented thus far, that the weight of filter cake to be handled and disposed of is much less than the weight of liquid sludge removed from sedimentation tanks and digestion tanks.

The suspended solids in the filtrate from vacuum filters (Table VI) vary from 110 to about 450 ppm. Elutriation data for a few installations are shown in Table VII.

Lagooning

Many municipalities in this country utilize lagoons (5) as an emergency or supplementary means for disposing of sludge when drying beds are inadequate, or when the capacities of existing installation of drying beds or other means of disposal, such as vacuum filters or incinerators, have been exceeded, or during temporary shutdowns of equipment for repairs. Sizeable municipalities are reporting use of lagoons. The Chicago Sanitary District (6) reports that in 1947 over 100,000 tons of undigested, dry solids from Imhoff tanks and activated sludge treatment process were disposed of to lagoons to supplement other means of disposal. The volatile content of this sludge was about 67.5 per cent. Lagoons have been used for disposal of undigested, activated sludge at Houston, Tex., and are still in use for all the sludge produced at Indianapolis, Ind. Rahway, N. J., has disposed of undigested, primary sludge in this manner. A number of cities, including Akron, Ohio; Baltimore, Md.; Battle Creek, Jackson, and Ann Arbor, Mich.; Dallas, Tex., etc., have utilized lagoons for disposal of digested sludges.

At Dallas, lagoons holding Imhoff sludge are discharged to the river twice a year during high water. At Dayton, Ohio, 31 per cent of the sludge was discharged to lagoons during 1946. At Toledo, Ohio, over 30,000 cu. yd. of sludge were discharged in 1947 to a marsh, whereas only about 11,500 cu. yd. were put onto the drying beds.

Indianapolis (7) has 13 lagoons covering an area of 55 acres, which amounts to about 6 sq. ft. of lagoon surface per capita; 12 of the lagoons remain in operation while one is being cleaned. The municipality furnishes a power shovel to load farmers' trucks; farmers get this sludge free of charge. Most of the hauling is done in winter when the ground is frozen. Primary settled and activated sludges are discharged to the lagoons, with solids content of 7.5 and 1.1 per cent, respectively. Sludge removed from lagoons has a solids content of 25 per cent and a nitrogen content of 2.5 per cent. The lagoon volume provided in various places varies anywhere from 0.4 to 6 cu. ft. per capita. Digested sludge at Baltimore compacted in the lagoons to 70 per cent moisture content.

TABLE III

Digested Sludge Removed from Drying Beds

Location	Year[1]	Type of Treatment	Sludge Vol. (cu. ft./cap./yr.)	Solids (%)
Springfield, Ill.	1942	Act. sludge	24.8[2]	50
Jackson, Mich.	1947	Act. sludge	2.80	36
San. Dist. of Chicago	1947	Imhoff tank	—	32
Elgin, Ill.	1945–46	Tr. filt., prim. and sec. settl.	0.67	40.5
Worcester, Mass.	1944	Imhoff, tr. filt., final settl.	2.92	—

[1] Annual report.
[2] Pounds.

TABLE IV

Sludge Dewatered on Vacuum Filters

Location	Year[1]	Type of Sludge	Sludge Applied to Filter		Sludge Cake Removed from Filter			Conditioning Chemicals	
			(lb./sq. ft.)	Solids (%)	Wet Cake (lb./sq. ft.)	Solids (%)	Dry Solids (lb./sq. ft./hr.)	CaO (%)	$FeCl_3$ (%)
(a) Primary Settled Sludge									
Minneapolis-St. Paul	1947	Raw	36.1	9.1	10.4	31.5	3.3	3.7	1.3
Washington, D. C.	1947–48	Dig., elutr.	98.0	8.0	28.0	27.7	7.8	—	3.6
Detroit, Mich.	1946–47	Part dig.	69.0	8.6	19.0	31.2	5.9	7.3	2.0
San Diego, Calif.	1947–48	Dig., elutr.	37.5	4.8	6.5	27.7	1.8	—	5.8
Cleveland, Ohio Westerly	1947	Imhoff, sep. dig.	43.5	7.8	10.4	32.9	3.4	11.0	2.8
Buffalo, N. Y.	1947	Digested	—	—	—	40.0	—	10.7	3.1
Hartford, Conn.	1948	Dig., elutr.	111.0	5.1	16.9	33.8	5.7	—	2.2
Springfield, Mass.	1947	Dig., elutr.	54.5	11.5	18.0	34.8	6.3	1.4[3]	0.6
San Francisco, Calif. Richmond Sunset	1944–45	Dig., elutr.	157.0	3.3	21.5	24.0	5.2	—	5.0
Dearborn, Mich.	Apr. 1948	Part dig., part chem. prec.	—	—	—	37.7	—	9.5	1.6
Auburn, N. Y.	Apr. 1949	Raw	10.9	5.6	20.0	30.0	6.1	20.0[2]	2.7
Wayne County, Mich. Wyandotte	1948	Raw set., chem. prec.	6.2	7.6	13.4	35.0	4.7	13.8	4.3
(b) Activated Sludge with Primary and Secondary Settling									
Columbus, Ohio	1948	Digested	—	—	—	25.3	—	16.0	4.1
Cleveland, Ohio[4]	1947	Digested	44.2	7.0	10.7	28.8	3.1	10.5	5.8
San. Dist. of Chicago Calumet	1947	Raw	—	2.6	—	17.2	—	—	5.6
Southwest	1947	Raw	—	1.5	—	16.1	—	—	—
New Britain, Conn.[5]	1944	Raw	61.5	7.5	16.5	28.0	4.6	35.0[2]	3.2
	1945–46	Raw	—	—	17.0	36.5	6.2	26.0[2]	2.4
Lansing, Mich.	July 1947	Dig. with garbage	—	—	15.0	31.2	4.7	8.4	4.3

[1] Annual report. [2] Aluminum sulfate. [3] Lime.
[4] Activated sludge from Easterly Imhoff, preaeration, and trickling filter; sludge from Southerly, all digested.
[5] Guggenheim process. [6] Prestoline.

TABLE V

Vacuum Filter Cake Produced

Location	Year[1]	Type of Sludge	Filter Cake (lb./cap./day)	
			Wet	Dry Solids
Minneapolis-St. Paul Sanitary District	1947	Settled, raw	0.67	0.21
Detroit, Mich.	1946–47	Settled, part dig.	0.38	0.12
Hartford, Conn.	1948	Settled, dig.	0.12	0.04
San Francisco, Calif Richmond Sunset	1944–45	Settled, dig.	0.12	0.03
Neenah-Menasha, Wis.	1948	Settled	3.35[2]	1.07[2]
Stamford, Conn	1948	Settled, dig.	0.10	0.03
Springfield, Mass.	1948	Settled, dig.	0.07	0.03
New Britain, Conn	1945–46	Guggenheim, settled	0.56	0.21
Lansing, Mich	July 1947	Act. dig. with garbage	0.42	0.13
Cuyahoga Falls, Ohio	1948	Act., settled	0.21	0.06
Tenafly, N J	1948	Act., settled	0.65	0.10

[1] Annual report.
[2] 0.38 and 0.12 lb. per cap per day, based on population equivalent.

TABLE VI

Suspended Solids in Filtrate from Vacuum Filters

Location	Year[1]	Type of Sludge	Susp. Sol. in Filtrate (p.p.m.)
Minneapolis-St. Paul	1947	Settled	110
Washington, D. C.	1947–48	Settled dig. elutr	160
Cleveland, Ohio Westerly	1947	Imhoff and sep. dig.	353
Southerly	1947	Dig., activated	457

[1] Annual report.

Use of lagoons for either digested or undigested sludges, in most cases, has resulted in complaints due to odors. Therefore, lagoons cannot be considered as a suitable permanent means of disposal, except in very isloated locations.

Heat Drying and Incineration

Many municipalities have adopted either heat drying of sludge to produce fertilizer or complete incineration as the means of final disposal of the sludge. Filter cake having a moisture content of 60 to 70 per cent can be burned without, or with very little, auxiliary fuel once combustion is started; the B.t.u. value of raw sludge, of course, is greater than for digested sludge. Heat drying of sludge requires auxiliary fuel, which can be supplied by the digester gas, or by oil or coal.

Burning of sludge requires a temperature of 1,000° to 1,200° F. Deodorizing temperatures of at least 1,100° F. are required for odor control in critical locations. Drying takes place at a temperature of 700° F., which is considered high enough to kill bacteria, even in undigested sludge.

Dryer-incinerators have been generally used where it was found desirable only to dry sludge, or to burn it or dry it at will. Multiple-hearth incinerators are to be in-

TABLE VII

Elutriation Data

Location	Ratio of Wash Water to Sludge Volume	Alkalinity (p.p.m.)		Elutriate		
		Digested Sludge	Elutriated Sludge	Susp. Solids (p.p.m.)	Alkalinity (p.p.m.)	5-Day B.O.D. (p.p.m.)
Washington, D. C.	1.5	3,100	790	2,950	1,600	660
San Diego, Calif.	—	4,000	1,168	—	—	—
Hartford, Conn.	3.0	2,982	224	—	804	—

stalled at Toronto, Ont., suitable for either burning or drying of sludge filter cake. Milwaukee, Wis., dries sludge with rotary dryers. Although early experience in drying sludge was with rotary dryers, very few have been installed for that purpose in recent years.

A spray dryer has been in operation at Plainfield, N. J. (8), for a number of years; experimentation with the method of distributing the sludge through the drying tower is still going on. The spray dryer has been used on liquid sludge and on filter cake.

Stamford, Conn. (9), utilizes stack gases from the refuse incinerator to pre-dry the sludge filter cake from primary digested sludge. The sludge is pre-dried to a moisture content of about 6 to 10 per cent, in which condition it can be sold as fertilizer or burned in the refuse incinerator.

It appears that sludge produced by chemical precipitation, or by complete treatment, has too high a water content for direct burning with refuse without first pre-drying.

Several manufacturers have advocated a mechanically stoked refuse incinerator con-

TABLE VIII

Heat Drying of Sludge and Disposal by Incineration

Plant No.	Plant Location	Year	Population[1] Tributary	Population[1] Equivalent Load	Type of Sludge	Filter Cake Moisture (%)[1]	Filter Cake Vol. Sol. (%)	Filter Cake To Dryer (tons/hr.)	Filter Cake Burned (tons/day)	Dryer Make	Dryer Oper. (hr./yr.)	Dryer H_2O Evap. (tons/ton dry sol.)
	(a) Heat Drying											
1	San. Dist. of Chicago, Ill. Calumet	1947	—	415,000[2]	Act. settled	82.8	—	106[3]	—	Raymond system	—	4.9
2	Southwest	1947	—	2,900,000[2]	Act. settled	83.9	—	475[3]	—	Raymond system	—	4.6
3	Battle Creek, Mich.	1948[4]	43,300	53,800	Prim. settled, dig.	78.5	—	1.9	—	Raymond system	578	3.5
4	Duluth, Minn.	1948	80,000	124,300	Prim. settled, dig.	74.6	—	1.6	—	Raymond system	527	2.9
5	Tenafly, N. J.	1948[4]	9,500	9,500	Act. settled	85	—	0.63	—	Raymond	1,460	5.4
6	Sheboygan, Wis.	1948[4]	45,200	68,400	Prim. settled, dig.	65.4	—	1.26[3]	—	Raymond system	1,826	1.8
7	Stamford, Conn.	1948[4]	45,000	67,500	Prim. settled, dig.	67	—	1.5	—	Raymond	560	2.0
8	San Diego, Calif.	1948	300,000	—	Prim. settled, dig.	72.3	—	—	—	Raymond system	—	2.5
9	Lansing, Mich.	1947[5]	82,000	—	Act., dig. with garbage	68.8	—	1.7	—	Morse Boulger	10.1[16]	1.85
	(b) Disposal by Incineration											
10	Minneapolis-St. Paul, Minn. Cleveland, Ohio	1947	900,000	1,230,000	Prim. settled	68.5	64.0	—	335	—	—	—
11	Westerly	1947	—	—	Prim. settled, dig.	66.8	44.4	—	19	—	—	—
12	Southerly	1947	—	—	Act., dig.	71.1	45.0	—	142	—	—	—
13	Columbus, Ohio	1948[13]	—	—	Act., dig.	74.7	40.0	—	32	—	—	—
14	Detroit, Mich.	1946–47[14]	2,400,000	—	Prim. settled, partially dig.	68.8	56.0	—	360	—	—	—
15	Wayne County, Mich.[15]	1948[14, 15]	—	—	Part settled, part chem. prec.	66	45	—	45[17]	—	—	—
16	Buffalo, N. Y.	1947–48	620,000	920,000	Settled, dig.	60	56.1	—	56	—	—	—
17	Cuyahoga Falls, Ohio	1948[5]	30,000	—	Act. settled	70	52.4	—	0.75[18]	—	—	—
18	Neenah-Menasha, Wis.	1948	24,000	216,000	Prim. settled	68	44	—	2.0[18]	—	—	—
19	Springfield, Mass.	1948	140,000	160,000	Prim. settled, dig.	62.2	43.4	—	1.4[18]	—	—	—
20	New Haven, Conn.	1948[21]	—	—	Prim. settled, dig.	72.7	52.7	—	1.13[18]	—	—	—
21	Duluth, Minn.	1948	80,000	124,300	Prim. settled, dig.	74.6	47.0	—	1.61	—	—	—
22	Piqua, Ohio	1948[22]	—	—	Prim. settled[24]	85.8	74.7	—	0.85[18]	—	—	—

Plant No.	Incinerator Make	Incinerator Oper. (hr./yr.)	Incinerator H_2O Evap. (tons/ton comb.)	Auxiliary Fuel Per Ton Dry Solids Oil (gal.)	Per Ton Dry Solids Gas (cu. ft.)	Per Ton Dry Solids Power[1] (kw.-hr.)	Per Ton Water Oil (gal.)	Per Ton Water Gas (cu. ft.)	Per Ton Filter Cake Oil (gal.)	Per Ton Filter Cake Gas (cu. ft.)	Per Ton Filter Cake Power[1] (kw.-hr.)	Moisture in Dried Sludge (%)
	(a) Heat Drying											
1	—	—	—	—	—	—	26	—	21	—	—	5.9
2	—	—	—	—	—	—	—	—	—	—	—	4.5
3	—	—	—	—	—	58	—	4,700	—	3,620	13	11
4	—	—	—	—	—	—	—	5,420[6]	—	4,000	12	3
5	Pittsburgh-Des Moines[6]	—	—	—	—	142	6.7	—[7]	5.6	—[7]	22	15
6	—	—	—	—	—	—	—	—	—	—	—	9.8
7	Pittsburgh-Des Moines[6]	—	—	—	—	75	—	—[7]	—	—[7]	40	6
8	—	—	—	—	—	74	—	6,670[6]	—	4,630	22	10
9	—	—	—	—	—	—	Negl.	As needed	Negl.	As needed	—	26.1[11]
	(b) Disposal by Incineration											
10	Nichols Herreshoff	—	3.7	0.60	—	9.6	—	—	0.19	—	3.0	—
11	Nichols Herreshoff	—	4.5	0.72[12]	4,300[12]	—	—	—	0.24[12]	1,420[12]	—	—
12	Nichols Herreshoff	—	5.6	—	1,280	—	—	—	—	370	—	—
13	Nichols Herreshoff	—	7.5	23.3	—	—	—	—	5.9	—	—	—
14	Nichols Herreshoff	—	3.8	0.55	—	—	—	—	0.18	—	—	—
15	Nichols Herreshoff	—	4.3	3.4	—	—	—	—	1.2	—	—	—
16	Raymond system[15]	8,278	2.7	0.22	3,800	—	—	—	0.09	1,510	—	—
17	Raymond system[20]	1,548	4.4	25.5	—	—	—	—	7.7	—	—	—
18	Raymond system[15]	7,208	4.9	35.9	—	—	—	—	11.5	—	—	—
19	Raymond system	1,240	3.3	—	2,000	65	—	—	—	800	27	—
20	Nichols Herreshoff	12[23]	4.9	33.2	2,700	—	—	—	9.4	760	—	—
21	Raymond system[15]	690[23]	6.3	—	2,730	48	—	—	—	700	12	—
22	Nichols Herreshoff	21[23]	8.2	88	—	—	—	—	12.2[25]	—	—	—

[1] Estimated. [2] From 1948 report on engineering work; part of sludge dried. [3] Tons per day. [4] Data from plant superintendent, by letter. [5] Deodorizing. [6] Garbage incinerator. [7] Incinerator gas. [8] Calculated. [9] Month of July. [10] Hours per day. [11] Ignites if dried to 10 per cent moisture. [12] 38 per cent oil and 67 per cent gas used during standby periods. [13] 10 months. [14] Data from monthly reports. [15] Wyandotte plant. [16] Month of September. [17] Based on days operated. [18] Deodorizing with preheater. [19] Tons per hour. [20] Deodorizing without preheater. [21] Month of January. [22] 7 months per year. [23] Sept. 7 to Dec. 31. [24] Liquid sludge not dewatered on vacuum filters. [25] Per ton liquid sludge.

structed with an auxiliary sludge drying hearth. Such a unit has been in operation at the Lederle Laboratories in Pearl River, N. J., for burning rubbish, sewage sludge, and spent media from laboratory processes. With adequate control of hot and cold gases, the two-hearth unit should be suited for burning a combination of sludge and garbage, but it has not been demonstrated whether dry sludge can be taken off for disposal other than burning.

Gas from digesters can be best utilized as auxiliary fuel for drying digested sludge, whereas if the sludge is incinerated, the digester gas can be utilized for power production or for other uses in the plant. At present there is a demand for organic fertilizers; dried sewage sludge can be sold at a good price, thus making it worthwhile to utilize the gas for drying sludge to make fertilizer.

Heat dried, undigested sludge has a higher fertilizer value and is, therefore, more valuable for this purpose than digested sludge. Due to the fact that the capital investment is high for providing digestion space for activated sludge, which has a high nitrogen content when undigested, economics at the present time favor heat drying in undigested form to produce fertilizer.

The price of heat dried activated sludge has been as high as $28.00 per ton, is currently around $18.00 to $20.00 per ton, and is not expected to go much lower than $12.00 per ton. At prices below $12.00 per ton, it would be more economical to burn the sludge than to dry it for fertilizer.

Houston, Tex. (10), and Los Angeles, Calif., are typical examples of the larger cities that have recently adopted heat drying of activated sludge to produce fertilizer. The plans for the proposed treatment plants at Harrisburg, Scranton, Bradford, and Bloomsburg, Pa., provide for either drying the sludge to produce fertilizer, or completely burning it.

The sludge produced at Harrisburg will be primary settled and digested, but flexibility will make it possible to dry or to incinerate undigested sludge. The sludge produced at Bloomsburg will be from chemical precipitation of sewage, which includes a large amount of industrial wastes. This undigested sludge will be dewatered on vacuum filters and burned with refuse consisting of rubbish and garbage. Undigested sludge from partial activated sludge treatment will be burned with refuse in the proposed Bradford plant. The incinerator-dryer at Scranton will operate on undigested, activated sludge, using coal as auxiliary fuel.

Pertinent data on heat drying of sludge are shown in Table VIIIa. The Sanitary District of Chicago heat dries undigested activated sludge at the Calumet and Southwest plants to produce fertilizer. The moisture content of the filter cake at Calumet averages 82 per cent; at the Southwest plant, 83.9 per cent. The sludge is dried to a moisture content of about 5 to 6 per cent. Primary settled and digested sludge is heat dried at Battle Creek, Mich.; Sheboygan, Wis.; and Stamford, Conn. The filter cake ranges from 65 to 80 per cent in moisture content, and the sludge produced ranges from 6 to 11 per cent in moisture content. Undigested, settled, activated sludge is heat dried at Tenafly, N. J. (Figure 2), and either sold as fertilizer or incinerated with refuse. The filter cake has a moisture content of 85 per cent, and the heat dried sludge a moisture content of 15 per cent. In the plants referred to above, flash dryers are utilized for drying the sludge and the sludge furnaces for incineration, except at Tenafly and Stamford, where incineration takes place in a refuse incinerator.

Activated sludge is digested, with ground garbage at Lansing, Mich. (11). The digested sludge is dewatered on vacuum filters and burned in a multiple-hearth incinerator. An endeavor also has been made to dry the sludge in this type of incinerator; the data shown for July, 1947, are typical for this operation. Sludge can be dried to a moisture content of about 25 per cent. Efforts to dry the sludge to a 10 per cent water content have resulted in ignition and burning of the sludge. As no charge is made for dried sludge, the moisture content of the final product is of no particular concern in this case.

At Grand Rapids, Mich., sludge taken off the drying beds is passed through a grinder and a rotating drum dryer and is placed in 100-lb. bags for sale as "Rapid Gro" fertilizer.

Data pertaining to sludge disposal by incineration are presented in Table VIIIb. Most of the incinerators are utilized for burning either primary settled sludge, or digested sludge from either primary sedimentation or activated sludge. Dearborn and Wayne County, Mich., Wyandotte plant burn part settled and part chemically precipitated sludge, both undigested. The Cuyahoga Falls, Ohio, plant burns activated sludge. All of these sludges, of course, are dewatered on vacuum filters before burning.

In the multiple-hearth furnaces, the wet filter cake is introduced at the top hearth and, by means of rabble arms, is moved to each successive next lower hearth. Combustion takes place in the third or fourth hearth from the top; ash is removed from the lowest hearth. The multiple-hearth incinerator has apparently been more widely used for complete burning of sludge than the flash dryer type.

In the flash dryer type, sludge is first pre-dried with the hot gases returned from the combustion chamber, and then the predried sludge is burned in the combustion chamber of the incinerator. A portion of the dried material has to be returned to the filter cake so that the wet filter cake can be properly handled in the flash dryer.

The larger installations operate the incinerators on a 24-hr. basis, or else keep the furnace hot with standby fuel. The smaller installations are operated intermittently, as needed, during 6 to 8 hr. per day and, in some cases, are allowed to cool down between burning operations.

The amount of auxiliary fuel used varies with the character of the sludge, the mode of operation, and the type of incinerator.

A multiple-hearth furnace was operated at Piqua, Ohio (12), in an endeavor to burn liquid sludge without first dewatering it on a vacuum filter. Data for this type of operation are presented in Table VIIIb. The tons of water evaporated per ton of combustible solids amounted to 8.2. This was much higher than usually results in the burning of vacuum filter sludge cake. The amount of auxiliary fuel required was excessive, 88 gal. being required per ton of dry solids, and 12.2 gal. per ton of liquid sludge. Under normal conditions sludge probably can be more economically disposed of by dewatering on vacuum filters and burning the sludge filter cake, especially where it is not possible to concentrate the sludge to the extent accomplished at Piqua.

Drying and Incineration Temperatures

Temperatures in the various hearths of a multiple-hearth furnace, as reported for the Cleveland Westerly plant in the incineration of sludge cake, and at Piqua, Ohio, in burning liquid sludge, are shown in Table IX. Operating temperatures prevailing in Raymond system dryers and incinerators for various installations are shown in Table X.

Information pertaining to the use of deodorizing equipment is also shown in Table X, as well as the per cent of design capacity at which the various incinerator-dryer in-

TABLE IX

Incineration Temperatures, in Degrees F.

	Cleveland, Ohio Westerly[1]	Piqua, Ohio[2]	
		Starting	Norm. Oper.
Material burned	Sl. cake	Liquid sl.	Liquid sl.
Hearth No. 1	870	730	750 to 1,030
Hearth No. 2	1,120	950	970 to 1,200
Hearth No. 3	1,270	1,180	1,150 to 1,350
Hearth No. 4	1,210	1,400	1,500 to 1,680
Hearth No. 6	510	990	980 to 1,300
Preheater inlet	320	—	—
Preheater outlet	680	—	—
Cooling air, top of shaft	410	300	440 to 520

[1] 1947 annual report.
[2] 1948 data by letter.

TABLE X

Operating Temperatures and Deodorizing Equipment, Raymond System Dryer Incinerators[1]

	Cuyahoga Falls, Ohio	San Diego, Calif.	Neenah-Menasha, Wis.	Tenafly, N. J.	Sheboygan, Wis.	Stamford, Conn.	Springfield, Mass.	Duluth, Minn.
Temperature, av (°F.)								
Cage mill inlet	1,200	1,000	1,200	1,800	720	950–1,100	1,200	1,000
Cyclone discharge	350	250	275	275	275	225–275	230	250
Combustion air	—	400	200	—	180	—	150	340
Stack	550	400	500	—	460	—	400	430
Deodorizing equipment								
Installed	Yes	Yes	Yes	Gases to	Yes[2]	Gases to	No	Yes
Temperature (°F.)	1,000	1,050	1,100	garbage	1,100	garbage	—	—
Fuel used, oil (gal.)	—	—	—	incin.	8	incin	—	—
Preheater used	No	Yes	Yes	—	Yes	—	—	Yes
Operation (% of des. cap.)	106	125	100	165	65	60	104	107

[1] Data by letter.
[2] Used 20 per cent of time.

TABLE XI

Heat Value and Volatile Content of Sludge

Plant	Year	Heat Value (B.t.u./lb.)		Vol. (%)
		Dry Sol.	Vol.	
Chicago, Ill. (Calumet)	1947	6,500	10,800	60.1
Cleveland, Ohio	1947	5,350	11,900	45.0
Buffalo, N. Y.	1947–48	5,282	—	36.1
Springfield, Mass.	1948	4,000	—	43.4

stallations are operated. It is reported that the high temperatures maintained during operation at Piqua are for eliminating odors in the burning of liquid sludge. Auxiliary fuel required and temperatures in drying and incineration units are affected by the extent of deodorization, and whether deodorization is accomplished with or without a pre-heater.

B.t.u. and Volatile Content

The B.t.u. value and volatile content of sludge at several installations are shown in Table XI.

Incinerator Ash Disposal

Ash is disposed of as fill in most cases. At Cuyahoga Falls, Ohio; Duluth, Minn.; and Springfield, Mass., it is pumped hydraulically to fill. At Neenah-Menasha, Wis., it is trucked dry to fill. The ash at Minneapolis and Detroit amounts to 0.07 lb. per capita per day; at Buffalo, 0.053 lb. per capita per day. Duluth reports the weight of ash as 45 lb. per cu. ft.

Disposal of Filter Cake

Digested sludge, dewatered on vacuum filters, can be disposed of without nuisance for fill in the same manner as digested sludge taken off the drying beds, or may be used for fertilizer. Washington, D. C. (13), in 1947, shipped to the Department of Correction at Lorton, Va., in freight cars, about 22,000 tons of digested sludge filter cake having a solids content of about 28 per cent. This was 92.4 per cent of the total sludge filter cake production of the plant. The sludge was applied to the soil or stored for future use. It is reported, however, that this sludge has not replaced the use of fertilizer. The remainder of the sludge was hauled by farmers in trucks for use as soil dressing.

Hartford, Conn. (14), disposes of its digested sludge filter cake in a dump, which has caused no particular trouble. Sludge is carried to the dump in cars operating on a narrow gage railroad. The amount of filter cake produced at Hartford is about 0.5 cu. ft. per capita per day.

About 8 tons of raw sludge filter cake has been disposed of as fertilizer at the Minneapolis-St. Paul Sanitary District. This amounts to somewhat less than 2.5 per cent of the plant's filter cake production.

Undigested sludge filter cake removed from the chemical precipitation and settling of sludge at Perth Amboy, N. J., has been disposed of in a dump. Similar sludge disposed of at Dearborn, Mich., before the incinerator was installed gave trouble due to odors when storm drainage leached out the lime.

Disposal by Digestion with Garbage

Ground garbage is added to the digesters at Lansing, Mich., and Marion, Ind. (18).

TABLE XII

Disposal of Sludge by Digestion with Garbage

Item	Lansing, Mich.	Marion, Ind.[1]
Year	1948	1948
Garbage, wet (lb./cap./day)	0.75	0.230
Dry solids in wet garbage (lb./cap./day)	0.13	0.035
Dry org. sol. in wet garbage (lb./cap./day)	0.135	0.033
Dry org. sol. in sewage (lb./cap./day)	0.27	0.16
Solids in green garbage (%)	20	15
Volatile in garbage (%)	90	91

[1] Whey also added with garbage; average dry solids content 0.0084 and volatile dry solids 0.0075 lb. per capita per day.

TABLE XIII

Incineration of Filter Cake with Garbage and Rubbish

	Frederick, Md.	Bradford, Pa.[1]	Bloomsburg, Pa.[1]	
			Canneries Operating[2]	Canneries Not Operating[3]
Year	1948	—	—	—
Type of sludge	Prim. settled	Activated	Chem. prec.	Chem. prec.
Pre-drying	No	Yes	Yes	Yes
Garbage and rubbish, wet (tons/yr.)	4,914	11,100	850	4,150
(lb./cap./day)	1.5	2.53	2.11	2.11
Sludge, wet (tons/yr.)	1,698	5,600	475	1,825
(lb./cap./day)	0.52	1.28	1.18	0.93
Dry solids (tons/yr.)	501	1,020	141	550
(lb./cap./day)	0.16	0.23	0.35	0.28
Water evap. (tons/yr.)	1,190	4,580	332	1,275
(lb./cap./day)	0.36	1.05	0.83	0.65
Water in filter cake (%)	70	82	70	70
Vol. in dry solids (%)	—	67	67	67
Ratio (weight), wet rubbish and garbage to:				
Wet filter cake	2.9	2.0	1.8	2.3
Water in filter cake	4.1	2.4	2.6	3.2
Dry sol. in filter cake	9.8	10	6.0	7.6
Water evap. from sludge (tons/ton comb.)	—	6.7	3.5	5.0
Ash produced (tons/yr.)	426	—	—	—
(lb./cap./day)	0.13	—	—	—

[1] Design basis of proposed installations.
[2] 2 months.
[3] 10 months.

In both places, sewage treatment consists of primary settling, activated sludge, and final settling. Cheese whey is also added directly to the digester at Marion.

Data pertaining to the addition of garbage to the digester are shown in Table XII. Normally, about 5 cu. ft. per capita of digestion space is required for complete treatment by the activated sludge process. When the garbage is added to the digester the space requirement for digestion is indicated to be from 9 to 10 cu. ft. per capita for complete digestion.

A number of municipalities add ground garbage to raw sewage. Except for increasing the solids to be handled, no basic processes for sludge disposal are affected (16).

Disposal of Liquid Sludge

Liquid digested sludge is disposed of at Marion, Ind., by conveying it with tank trucks and spreading it on land (17). In 1948, over 5 m.g. of sludge having a solids content of 4.2 per cent and volatile content of 49.7 per cent was disposed of in this manner. About 75 per cent of the sludge was handled in a 1,500-gal. tank truck; the remainder, in a smaller truck. The average haul is calculated to be about 40 mi. Based on figures given for the cost of hauling with the 1,500-gal. truck, it appears that the cost of disposal amounts to $7.20 per 1,000 gal., or about $4.55 per ton of dry solids. The revenue derived from the sale of liquid sludge amounted to about $1,400.

New York City operates and maintains boats to haul liquid digested sludge to sea as a means of disposal. This method also is utilized by other coastal cities and, in some cases, undigested sludge is taken out to sea for disposal. At Elizabeth, N. J., undigested, primary settled sludge is concentrated by storage before such sea disposal (18).

Incineration of Filter Cake with Garbage and Rubbish

Primary settled sludge, undigested, is dewatered on vacuum filters and burned in an incinerator with garbage and rubbish at Frederick, Md. (22). The filter cake has a moisture content of about 70 per cent; the ratio of wet garbage and rubbish to wet filter cake is 2.9 to 1. In order to burn the sludge with refuse successfully, it has to be proportioned manually so that the proper ratios of refuse and sludge filter cake are maintained for satisfactory incineration. The ratio of wet garbage and rubbish to dry solids and wet filter cake is about 10 to 1. The ash produced from the burning of sludge and garbage amounts to 0.13 lb. per capita per day. Data pertaining to the burning of sludge filter cake with garbage and rubbish (Table XIII) show the results obtained in Frederick, and for two proposed installations where sludge is to be predried.

Disposal of sludge by burning or drying in combination with the incineration of refuse consisting of rubbish and garbage is a method being adopted quite generally. The burning of refuse provides enough heat for incineration of filter cake from primary undigested sludge without the use of appreciable amounts of fuel. Due to the high ratio of water in filter cake from undigested, chemically precipitated sludge or activated sludge to refuse, it is necessary to pre-dry such sludge before burning with refuse.

Digested sludges having a high ratio of water to be evaporated to their volatile contents probably also would have to be predried before they could be burned with refuse.

Analyses of Sludge

Moisture, volatile, and other ingredients of various sludges, as well as fertilizing values for various installations, are shown in Table XIV. Data on sludge from sand beds, vacuum filters, heat dried, are presented. It is of interest to note that in the filter cake dumped at Hartford, Conn., over a period of years the volatile solids content, ranging from 48 to 70 per cent, was reduced to about 36 per cent. The moisture content was reduced from 66.2 per cent to 42 per cent. The other constituents remained practically the same, but the potash content was less in the material from the dump. Further analyses of some of the installations are shown in Table XV.

Sludge Sold or Prepared for Fertilizer

Data pertaining to sludge sold or prepared for fertilizer in various municipalities

TABLE XIV

Analyses of Dewatered Sludges

Location	Year[1]	Type of Sludge	Moisture (%)	Vol. (%)	Humus (%)	K_2O (%)	P_2O_5 (%)	N (%)	NH_3 (%)	Fats
Racine, Wis.	1946	Set., dig., sand beds	43.0	—	47.0	0.5	2.5	—	2.9	—
San. Dist. of Chicago, Ill.										
West Side	1947	Imhoff, sand beds	68.0	48.8	—	—	—	2.15	—	—
Southwest	1947	Raw set.	86.5	63.2	—	—	2.4	—	6.4	—
Calumet	1947	Act. } Vac. filt., heat dried	94.1	60.1	—	—	2.9	4.9	5.6	6.6
Cleveland, Ohio, Southerly	1947	Act. set., dig. (Drying bed	—	47.7	—	—	1.7	3.8	—	14.8
		Vac. filt.	—	43.8	—	—	1.5	3.2	—	12.2
Hartford, Conn.	1938-43	Prim. set., dig. (Vac. filt.	66.2	47.7 to 70.0	30.0 to 53.0	0.2 to 0.5	1.3 to 2.4	1.7 to 2.3	2.0 to 2.8	—
		Dump	42.0	26.0	35.0	0.10	1.8	1.9	2.3	—
Grand Rapids, Mich.	—	Prim. set., dig., sand beds, heat dried	9.1	49.3	6.5	—	2.50	—	2.5	—
San Diego, Calif.	—	Prim. set., dig., vac. filt., heat dried	10.0	69.0	—	0.13	2.50	3.0	—	—
Tenafly, N. J.	1937-41	Raw act. set., vac. filt., heat dried	15.0	72.4	—	0.5	3.6	—	7.0	—
Sheboygan, Wis.	1948	Prim. set., dig., vac. filt., heat dried	9.8	44.0	—	0.13	1.5	2.2	—	—
Stamford, Conn.	1948	Prim. set., dig., vac. filt., heat dried	6.0	44.0	—	Trace	1.0	3.0	—	—
Springfield, Mass.	1948	Prim. set., dig., vac. filt., heat dried	—	43.4	30.0	0.50	2.40	2.0	—	—
Wilmington, Ohio	1940[2]	Chem. prec., sand beds	—	—	—	0.28	3.75	—	2.01	—
Lebanon, Ohio	1940[2]	Chem. prec., sand beds	—	—	—	0.31	1.31	—	0.8	—

[1] Operation report.
[2] Report of test period.

are shown in Table XVI. Information is also included on the price per ton received for sludge sold as fertilizer and total revenue where information is available.

Dayton, Ohio, reports gross revenue of $10,441.91, with a profit of $6,410.59, from the sale of sludge for fertilizer in 1946; San Diego derived a revenue of $18,117.60 for the 1947-48 year. Grand Rapids (20) disintegrates the sludge dried on sand beds, and after final heat drying sells it for fertilizer. A total revenue of $7,737 was derived from the sale of sludge in 1947.

TABLE XV

Analyses of Sludges

Location	Lime, as CaO (%)	Sulfates (%)	Fe_2O_3, Al_2O_3 (%)	SiO_2 (%)
Cleveland, Ohio, Southerly				
Drying beds	2.3	2.6	11.4	35.2
Vacuum filters	15.1	2.8	15.7	22.2
Grand Rapids, Mich.	9.5[1]	—	—	—
Hartford, Conn.	—	—	—	0.4 to 1.2[2]

[1] Lime.
[2] As Fe.

Conclusions

Sufficient experience is available to indicate that nearly all types of sludges can be dewatered, dried, or incinerated mechanically. Sanitarians no doubt will agree that complete incineration, resulting in an inert ash, affords the most satisfactory solution of a very difficult problem. However, because of the present great demand for organic fertilizers and organic humus, it seems wrong to destroy such organic material. The combination permitting drying or incineration offers the answer which meets many situations. Organic matter is conserved by drying only when the demand exists; the sludge can be incinerated when there is no demand for sewage sludge fertilizer, or when economics are adverse to its conservation.

Dewatering of undigested sludge, although it can be done, only solves the problem partially. The water is removed, but putrescible organic matter still remains. Dewatering of digested sludge on vacuum filters provides as good a solution as drying on beds, and sludge can be disposed of in the same manner as bed dried sludge. The vacuum filter method minimizes the manual problem in handling and taking sludge off the beds, which is quite material for large cities.

Lagooning of sludge is a temporary expedient. It is believed that most engineers will agree that, except in unusual situations, it cannot be considered as a permanent means of sludge disposal. At best, it can serve only until other means are provided.

Disposal of sludge at sea has thus far been acceptable, even for as large a city as New York. Restrictions may be placed on this type of disposal in the future, requiring barging of sludge to greater distances. When the distance which sludge must be hauled becomes sufficiently great, economics will lead to mechanical dewatering and incineration of sludge, at least for the larger cities.

From a functional standpoint, there is no reason why mechanical dewatering, drying, and incineration of sludge should not suit every municipality. Economically, this method is limited to larger cities, and drying of sludge on beds will be the best answer for the smaller municipalities for many years to come unless, in exceptional cases, use of digestion and drying beds is limited by restrictions of available plant site. Therefore, the smaller municipalities can be best served by disposing of sludge by digestion and drying beds, larger municipalities by dewatering digested sludge, and the still larger municipalities by dewatering and drying or burning of any sludge.

Dewatering sludge on vacuum filters and burning it with garbage and refuse, either with or without pre-drying, changes the economics so that the range of the smaller municipalities which can afford disposal of sludge by burning is extended. This also applies to municipalities where garbage is ground and added to the sewage or to the digesters.

Acknowledgements

Acknowledgment is accorded Messrs. Robert D. Nickerson, of Combustion Engineering-Superheater, Inc., and M. A. Clift, of Nichols Engineering and Research Corporation, for their assistance in obtaining much of the data on drying and incineration of sludge from the various plant superintendents and from their own files for use in preparation of this paper.

TABLE XVI

Sludge Sold or Prepared for Fertilizer

Location	Year[1]	Sludge						
		Type	Sold or Prepared (tons/yr.)	Moisture (%)	How Dried	Unit Weight (lb./cu. ft.)	Price ($/ton)	Total Revenue ($)
Battle Creek, Mich.	1948	Set., dig.	250	11	Flash dryer	30.4	14 to 20	—
Sheboygan, Wis.	1948	Set., dig.	724	9.5	Flash dryer	46.0	5.50	—
Stamford, Conn.	1948	Set., dig.	250	6	Flash dryer	30.0	5.35	—
San Diego, Calif.	1948	Set., dig.	905	10	Flash dryer	—	20	—
Duluth, Minn.	1948	Set., dig.	212	3	Flash dryer	—	12	—
Toledo, Ohio	1947	Set., dig.	950	—	Drying beds	—	—	9,525[3]
Washington, D. C.	—	Set., dig., vac. filt.	21,700	72.3	Vac. filter	—	None	None
Chicago, Ill. (Calumet)	1947	Set., act.	6,900	5.9	Flash dryer	—	—	—
Chicago, Ill. (Southwest)	1947	Set., act.	23,400	4.5	Flash dryer	—	—	—
Tenafly, N. J.	1948	Set., act.	163	15	Flash dryer	—	30 to 40	—
Marion, Ind.	1948	Act., dig.[4]	5,246[5]	95.8	Liquid	—	—	1,385[6]

[1] Annual report.
[2] Fertilizer processing cost $2.99 to $4.31 per ton.
[3] Ground garbage digested with sludge.
[4] Thousands of gallons.
[5] Digested liquid sludge trucked for disposal on farm land; some sold.

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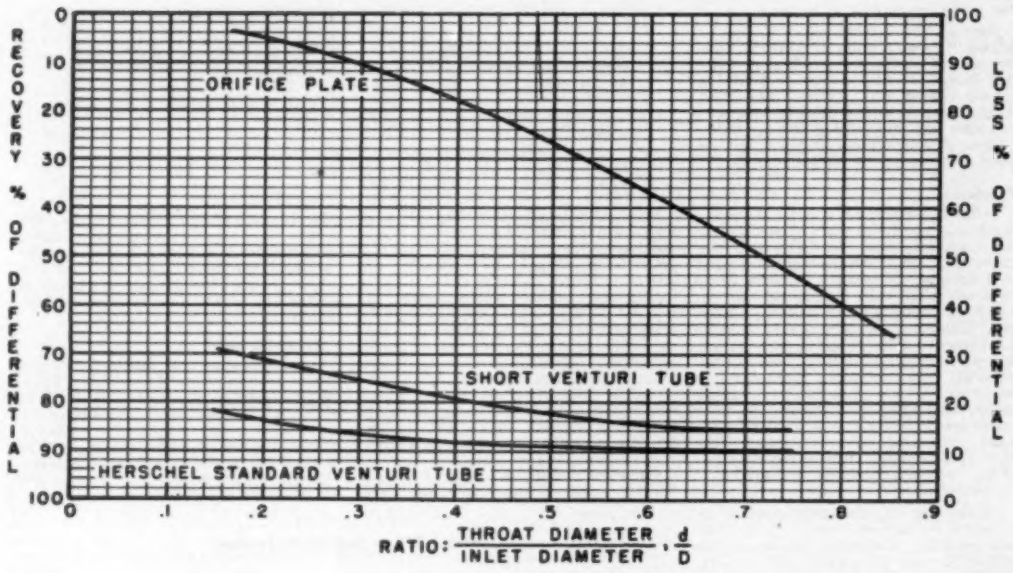
RECOVERY CHARACTERISTICS OF DIFFERENTIAL PRODUCERS*

Annual Power costs for various head losses on opposite page



The above graph shows the recovery characteristics for orifice plates, short Venturi Tubes, and the Herschel Standard Venturi Tube. From this graph it is possible to compute the loss of head at any selected rate of flow. Referring to Keep Sheet No. 1,** which shows the capacity of Venturi Tubes of various sizes, the differential for various flows may be obtained.

To compute the loss of head at any selected rate of flow, multiply the differential at that rate of flow by the percentage loss in head for the d/D ratio (throat dia. divided by inlet dia.) which applies. This loss may be taken from the above graph.

For example, assume that a meter designed for maximum differential of 100-in. of water is to be installed in a 10-in. line where maximum flow will be 900 gpm. with a normal flow of 75 per cent or 675 gpm. producing a differential of 56-in. Referring to Keep Sheet No. 1,** we find that the differential producer may be a 10 x 4 in. The above graph shows the loss of head for the Herschel Standard Venturi Tube as 12 per cent of the actual differential. Thus for a 56 in. differential, the loss is 6.7 in. or 0.56 ft.

For an orifice plate the above graph shows the loss to be 72 per cent of the differential or in this case 0.72 of 56 in. or 40.3 in., i.e., 3.35 ft.

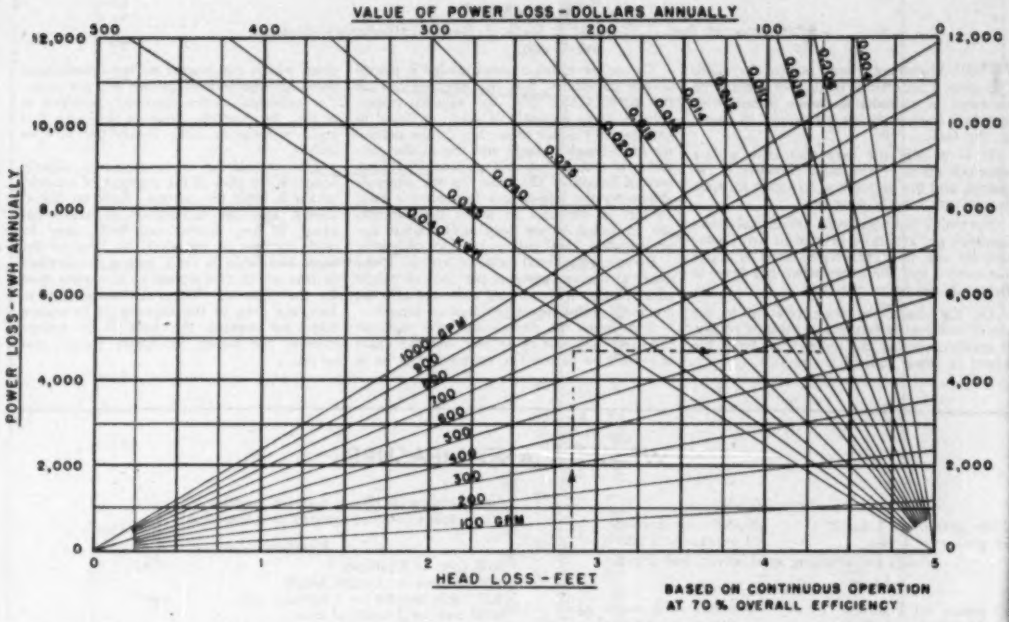
As shown from this example, by using a Venturi Tube the loss in head is 2.79 ft. less than when an orifice plate is used.

*Reprinted by permission from BIF INDUSTRIES Keep Sheet No. 3.

**"Venturi Tube Capacity Tables"—Keep Sheet No. 1—*The Courier*, Vol. 1, No. 2, March 1950; published by BIF INDUSTRIES, Providence, R.I.

ANNUAL POWER COSTS FOR VARIOUS HEAD LOSSES*

Recovery characteristics of Differential Producers on opposite page



The above figure provides a quick means of computing the value, in dollars per year, of power consumed due to loss of head, or conversely, the savings due to head recovery, assuming 70 per cent over-all pumping efficiency.

Starting with a known head loss, read vertically to the intersection with the curve indicating the proper quantity of flow, then horizontally to the right to the applicable cost per KWH, and then vertically upward to the annual value in dollars of power lost or saved.

For instance, take the same example shown in the top figure above, where the maximum flow is 900 gpm. and the normal flow is 75 per cent of maximum, or 675 gpm., producing a differential of 56 in.

From the curves and data on "Recovery Characteristics of Differential Producers" (previous page) the loss of head for this differential is only 6.7 in., or 0.56 ft., while for an orifice the loss is 3.35 ft. Thus, by using the Venturi Tube, the loss is 2.79 ft. less than for an orifice.

With 24-hr. pump operation at 675 gpm. (70 per cent over-all efficiency) and power cost of $0.015 per KWH, the above graph shows power cost saved amounts to $70 per year. This saving justifies an increased investment for the more efficient equipment.

If the pumping rate is higher than 1000 gpm. (the maximum rate on the graph) divide the pumping rate by 10, 100, or 1000, and proceed as before but multiply the result by the proper factor.

*Reprinted by permission from BIF Industries Keep Sheet No. 3.

Atmospheric Pressures & Barometric Readings at Various Altitudes

Altitude Ft.	Barometric Pressure Ins. of Mercury	Atmospheric Pressure Lbs. per sq.in.	Equivalent head of water in ft.	Boiling Point of Water °F.	Altitude Ft.	Barometric Pressure Ins. of Mercury	Atmospheric Pressure Lbs. per sq.in.	Equivalent head of water in ft.	Boiling Point of Water °F.
0	29.92	10.7	34.0	212.0	5000	24.89	12.2	28.2	202.9
500	29.38	14.4	33.3	211.1	5500	24.43	12.0	27.8	201.9
1000	28.86	14.2	32.8	210.2	6000	23.98	11.8	27.3	201.0
1500	28.33	13.9	32.2	209.3	6500	23.53	11.5	26.6	200.1
2000	27.82	13.7	31.7	208.4	7000	23.09	11.3	26.2	199.2
2500	27.31	13.4	31.0	207.4	7500	22.65	11.1	25.7	198.3
3000	26.81	13.2	30.5	206.5	8000	22.22	10.9	25.2	197.4
3500	26.32	12.9	29.8	205.6	8500	21.80	10.7	24.8	196.5
4000	25.84	12.7	29.4	204.7	9000	21.38	10.5	24.3	195.5
4500	25.36	12.4	28.7	203.8	10000	20.58	10.1	23.4	193.7

CONTENTS OF HORIZONTAL CYLINDERS

A Multiple Use Chart for Vertical as Well as Horizontal Tanks, Pipe Lines, Etc.

By J. TARRANT

Assoc. M. Inst. C. E., A. M. I. Mech. E. Ruislip (Middlesex), England

THE alignment chart printed herewith gives a convenient method of finding the contents of cylindrical tanks placed with the axis horizontal for all depths of liquid in the tank.

It is usually the case that only a fair approximation of the tank contents is required, and the calculation by exact formula is not very readily done.

Formulas for horizontal cylindrical tanks contents are generally printed in two forms, one for use when the liquid level is above the centre and the other when the level is below the centre of the tank.

On the chart, the scale relating to the depth of liquid is continuous; that is to say, it applies whether the liquid level be in the upper or lower half of the section.

To use the chart, a straightedge is placed across the scales, and the intersections on the three scales give the related values. Line A gives the ratio of depth of liquid to the diameter of the tank; line B, the diameter of the tank in feet; and line C, the contents, in cubic feet and gallons, for each foot of length of the tank. In the example shown by the line across the chart, a tank 15 feet in diameter in which the contents are 10 feet 6 inches deep, will contain approximately 1,000 gallons per foot of length.

By using the fixed value of h/d = 1, the chart also gives contents per foot of height of a cylinder with vertical axis, and also the contents of full pipes per foot of length.

Sometimes the dimensions of a tank or pipe line will not be in feet, but the chart may still be used. The contents will be in units which correspond to the dimensional units, and the scale of gallons will not apply. For example, if the diameter is taken in inches, the contents, *read on the cubic feet scale*, will be in *cubic inches* per *inch* of length.

The calculation of contents is clearly based on the area of the segment of a circle, which is what the contents scale on line C shows, and the calculation of segmental areas, in any dimensional units, may be made by use of the chart so long as the cubic feet scale is read, and units ascribed to this which correspond to the units used for the diameter. When the diameter is in feet, the area of the segment is in square feet; for meters, the area is in square meters; for inches, in square inches, and so on.

WEIGHTS AND MEASURES

Troy Weight

3.086 grains = 1 carat
24 grains = 1 dwt.
20 dwts. = 1 ounce
12 ounces = 1 pound

Used for weighing gold, silver, and jewels.

Apothecaries' Weight

20 grains = 1 scruple
3 scruples = 1 dram
8 drams = 1 ounce
12 ounces = 1 pound

The ounce and pound in this weight are the same as in Troy Weight.

Avoirdupois Weight

1 grain (Troy) = 1 grain (Apoth.) = 1 grain (Avdp.)

27 11/32 grains = 1 dram
16 drams = 1 ounce = 437.5 grains
16 ounces = 1 pound
25 pounds = 1 quarter
4 quarters = 1 cwt.
2,000 lbs. = 1 short ton
2,240 lbs. = 1 long ton
1 long ton = 1 British ton

Dry Measure

2 pints = 1 quart
1 quart = 67.2 cu. in.
1 British bushel = 1.032 U. S. Bushel
8 quarts = 1 peck
4 pecks = 1 bushel

Liquid Measure

4 gills = 1 pint
16 fluid ounces = 1 pint
2 pints = 1 quart
4 quarts = 1 gallon
1 British Imperial gallon = 1.200 U. S. gallons
1 cubic foot of water contains 7.48 gallons and weighs 62.321 lb.
1 gallon = 231 cu. in.
31½ gallons = 1 barrel
2 barrels = 1 hogshead

Linear Measure

1 mil = 0.001 inch
12 inches = 1 foot
3 feet = 1 yard
5½ yards = 1 rod
40 rods = 1 furlong
8 furlongs = 1 statute mile
5280 feet = 1 statute mile
3 miles = 1 league

Square Measure

1 circular mil = 0.7854 square mils
1,000,000 square mils = 1 square inch
144 square inches = 1 sq. ft.
9 sq. ft. = 1 sq. yard
4 roods = 1 acre = 43560 sq. ft.
30¼ sq. yds. = 1 sq. rod
40 sq. rods = 1 rood
640 acres = 1 sq. mile

Surveyor's Measure

7.92 inches = 1 link
25 links = 1 rod
4 rods = 1 chain
43560 sq. ft. = 1 acre
640 acres = 1 sq. mile
10 sq. chains or 160 sq. rods = 1 acre
36 sq. miles (6 miles square) = 1 township

Mariners' Measure

6.08 feet = 1 fathom
120 fathoms = 1 cable length
8.31 cable lengths = 1 nautical mile
6080 feet = 1 nautical mile
1 nautical mile = 1.15 statute mile
1 knot is a speed of 1 nautical mile per hour

Paper Measure

24 sheets = 1 quire
20 quires = 1 ream
2 reams = 1 bundle
5 bundles = 1 bale

Cubic Measure

1 cu. cm. = .061 cu. in.
27 cu. ft. = 1 cu. yd.
40 cu. ft. = 1 ton (shipping)
231 cu. in. = 1 standard gallon
2150.42 cu. in. = 1 standard bushel
1 cu. ft. = 4/5 of a bushel
1728 cu. in. = 1 cu. ft.
128 cu. ft. = 1 cord (wood)

Household Measure

60 drops = 1 teaspoon
2 teaspoons = 1 dessert spoon
3 teaspoons = 1 tablespoon
16 tablespoons = 1 cup
2 gills = 1 cup
2 cups = 1 pint

METRIC EQUIVALENTS

Linear Measure

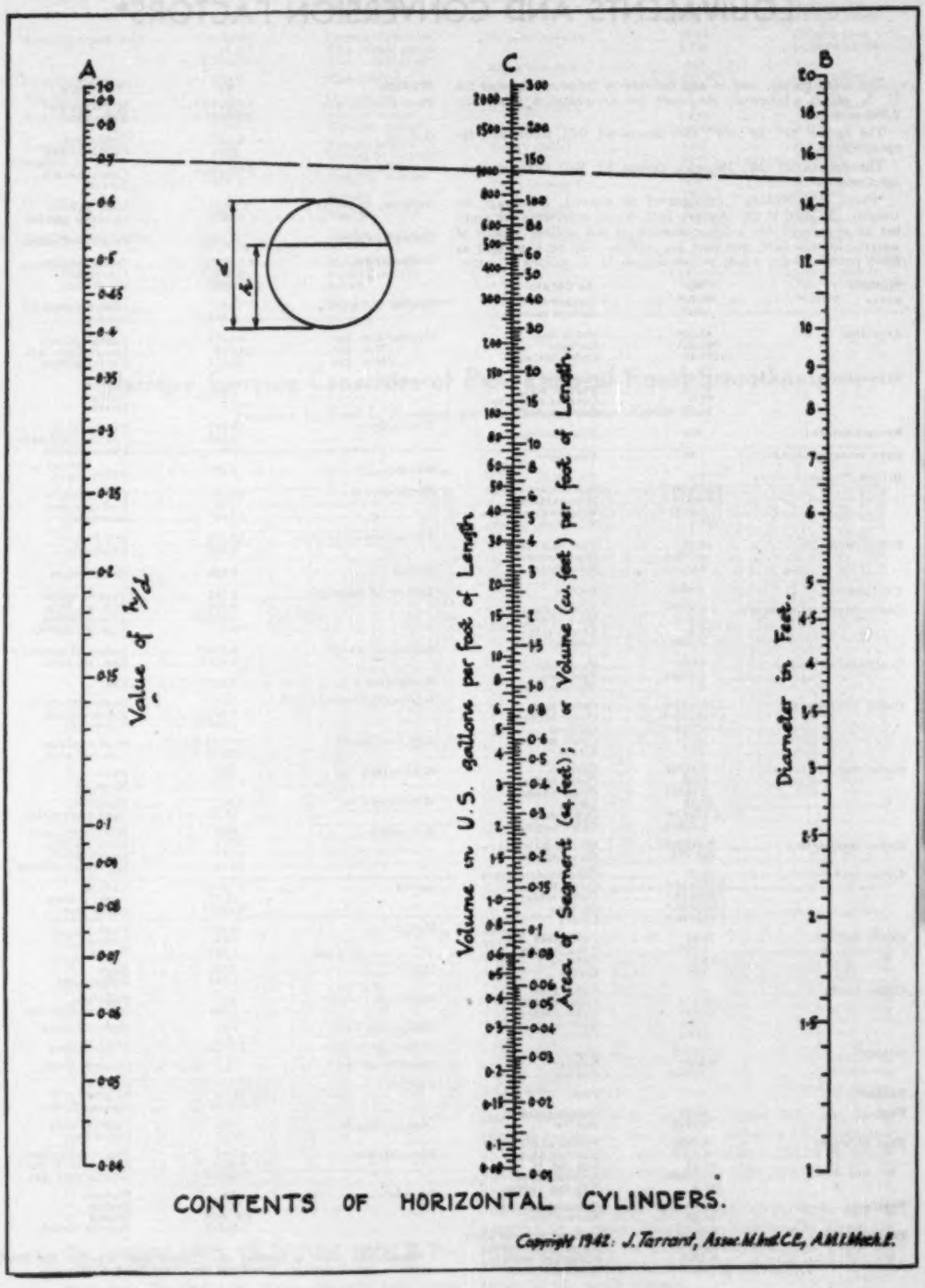
1 millimeter = 0.03937 inches
1 centimeter = 0.3937 inches
1 decimeter = 3.937 in. = 0.328 ft.
1 meter = 39.37 in. = 1.0936 yards
1 dekameter = 1.9884 rods
1 kilometer = 0.62137 mile
1 inch = 2.54 centimeters
1 foot = 3.048 decimeters
1 rod = 0.5029 dekameter
1 yard = 0.9144 meter
1 mile = 1.6093 kilometers

Square Measure

1 sq. cm. = 0.1550 sq. in.
1 sq. decimeter = 0.1076 sq. ft.
1 sq. meter = 1.196 sq. yds.
1 hectare = 2.47 acres
1 sq. kilometer = 0.386 sq. miles
1 sq. in. = 6.452 sq. cm.
1 sq. foot = 9.2903 sq. decimeters
1 sq. yard = 0.8361 sq. meter
1 sq. mile = 2.59 sq. kilometers

Weights

1 dyne = .00102 grains
1 gram = 0.03527 ounces
1 kilogram = 2.2046 lbs.
1 metric ton = 2205 lbs.
1 pound = 0.4536 kilograms
1 metric ton = 1.1023 short tons
1 ounce = 28.35 grams = 437.5 grains



CONTENTS OF HORIZONTAL CYLINDERS.

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EQUIVALENTS AND CONVERSION FACTORS*

The word gallon, used in any conversion factor, designates the U. S. gallon. Likewise, the word ton designates a short ton, 2,000 pounds.

The figures 10^{-1}, 10^{-2}, 10^{-3}, etc., denote 0.1, 0.01, 0.001, etc., respectively.

The figures 10^{1}, 10^{2}, 10^{3}, etc., denote 10, 100, 1000, etc., respectively.

"Parts Per Million," (designated as p.p.m.), is always by weight. As used in the sanitary field, p.p.m. represents the number of pounds of dry solids contained in one million pounds of water. In this field, one part per million may be expressed as 8.345 pounds of dry solids to one million U. S. gallons of water.

Multiply	By	To Obtain
Acres	43,560	Square feet
"	4047	Square meters
Acre-feet	43,560	Cubic feet
" "	325,851	Gallons
" "	1233.49	Cubic meters
Atmospheres	29.92	Inches of mercury
"	33.90	Feet of water
"	76.0	Cms. of mercury
"	14.70	Lbs./sq. inch
Barrels cement	376	Pounds—cement
Bags or sacks-cement	94	Pounds— "
British Thermal Units	777.5	Foot-lbs.
" " "	3.927×10^{-4}	Horse-power-hrs.
" " "	2.928×10^{-4}	Kilowatt-hrs.
" " "	0.2520	Kilogram-calories
" " "	107.5	Kilogram-meters
B.T.U./min.	12.96	Foot-lbs./sec.
" "	0.02356	Horse-power
" "	0.01757	Kilowatts
Centimeters	0.3937	Inches
Centimeters of mercury	0.01316	Atmospheres
" " "	0.4461	Feet of water
" " "	27.85	Lbs./sq. ft.
" " "	0.1934	Lbs./sq. inch
Centimeters/second	1.969	Feet/min.
" "	0.03281	Feet/sec.
" "	0.6	Meters/min.
Cubic centimeters	3.531×10^{-5}	Cubic feet
" "	6.102×10^{-2}	Cubic inches
" "	2.642×10^{-4}	Gallons
" "	10^{-6}	Cubic meters
" "	10^{-3}	Liters
Cubic feet	7.48052	Gallons
" "	1728	Cubic inches
" "	0.03704	Cubic yards
" "	28.32	Liters
" "	2.832×10^{4}	Cubic cms.
" "	0.02832	Cubic meters
Cubic feet/second	0.646317	Million gals./day
" " "	448.831	Gallons/min.
Cubic inches	16.39	Cubic centimeters
" "	5.787×10^{-4}	Cubic feet
" "	1.639×10^{-5}	Cubic meters
" "	4.329×10^{-3}	Gallons
" "	1.639×10^{-2}	Liters
Cubic meters	35.31	Cubic feet
" "	1.308	Cubic yards
" "	264.2	Gallons
" "	10^{3}	Liters
Cubic yards	27	Cubic feet
" "	46,656	Cubic inches
" "	0.7646	Cubic meters
" "	202.0	Gallons
" "	764.6	Liters
Drams	27.34375	Grains
"	0.0625	Ounces
"	1.771845	Grams
Fathoms	6	Feet
Feet	30.48	Centimeters
"	0.3048	Meters
Feet of water	0.8826	Inches of mercury
" " "	0.4335	Lbs./sq. inch
" " "	62.43	Lbs./sq. ft.
" " "	0.02950	Atmospheres
" " "	304.8	Kgs./sq. meter
Feet/sec.	30.48	Centimeters/sec.
" "	18.29	Meters/min.
Foot-pounds	1.286×10^{-3}	British thermal units
" "	5.050×10^{-7}	Horse-power-hrs.
" "	0.1383	Kilogram-meters
" "	3.766×10^{-7}	Kilowatt-hrs.
Foot-pounds/min.	3.030×10^{-5}	Horse-power
" " "	2.260×10^{-5}	Kilowatts
Gallons	0.1337	Cubic feet
"	231	Cubic inches
"	3785	Cubic centimeters
"	3.785×10^{-3}	Cubic meters
"	3.785	Liters
Gallons, Imperial	1.200095	U. S. gallons
" U. S.	0.83267	Imperial gallons
Gallons water	8.3453	Pounds of water
Gallons/min.	2.228×10^{-3}	Cubic feet/sec.
" "	0.06308	Liters/sec.
" "	8.0208	Cu. ft./hr.
Grains (troy)	1	Grains (avoir.)
"	0.06480	Grams
Grains/U.S. gal.	17.118	Parts/million
" /U.S. gal.	142.86	Lbs./million gal.
" /Imp. gal.	14.254	Parts/million
Grams	15.43	Grains
"	0.03527	Ounces
"	980.7	Dynes
Grams/liter	58.417	Grains/gal.
" "	8.345	Pounds/1000 gals.
" "	1000	Parts/million
Hectares	2.471	Acres
Horse-power	42.44	B.T. Units/min.
" "	550	Foot-lbs./sec.
" "	0.7457	Kilowatts
Horse-power (boiler)	33.479	B.T.U./hr.
" " "	9.803	Kilowatts
Inches	2.540	Centimeters
Inches of mercury	1.133	Feet of water
" " "	0.4912	Lbs./sq. inch
" " "	0.03342	Atmospheres
" " "	345.3	Kgs./sq. meter
Inches of water	0.07355	Inches of mercury
" " "	0.03613	Lbs./sq. inch
Kilograms	2.205	Lbs.
Kilograms-calories/min.	51.43	Foot-pounds/sec.
" " "	0.09351	Horse-power
" " "	0.06972	Kilowatts
Kgs./sq. meter	3.281×10^{-3}	Feet of water
" " "	1.422×10^{-3}	Lbs./sq. inch
Kilometers	3281	Feet
"	0.6214	Miles
Kilometers/hr.	0.9113	Feet/sec.
" "	27.78	Centimeters/sec.
Kilowatts	56.92	B.T. Units/min.
"	737.6	Foot-lbs./sec.
"	1.341	Horse-power
"	14.34	Kg.-calories/min.
Liters	0.2642	Gallons
"	61.02	Cubic inches
"	0.03531	Cubic feet
Meters	3.281	Feet
"	39.37	Inches
"	1.094	Yards
Miles	5280	Feet
"	1.609	Kilometers
Miles/min.	88	Feet/sec.
" "	1.609	Kilometers/min.
Milligrams/liter	1	Parts/million
Million gals./day	1.54723	Cubic ft./sec.
Miner's inches	1.5	Cubic ft./min.
Ounces	28.349527	Grams
"	437.5	Grains
"	0.9115	Ounces (troy)
Ounces (fluid)	1.805	Cubic inches
" "	29.57	Cubic cm.
Parts/million	8.345	Lbs./million gal.
" "	0.0584	Grains/U. S. gal.
" "	0.07016	Grains/Imp. gal.
Pounds	16	Ounces
"	7000	Grains
"	453.5924	Grams
"	1.21528	Pounds (troy)

*Selections from a booklet of—"Conversion Factors for Engineers"—distributed by The Dorr Co., New York City.

Multiply	By	To Obtain
Pounds of water	0.01602	Cubic feet
" " "	27.68	Cubic inches
" " "	0.1198	Gallons
Pounds/cubic feet	0.01602	Grams/cubic cm.
" " "	16.02	Kgs./cubic meter
" " "	5.787×10^{-4}	Lbs./cubic inch
Pounds/foot	1.488	Kgs./meter
Pounds/inch	178.6	Grams/cm.
Pounds/sq. foot	0.01602	Feet of water
" " "	4.823	Kgs./sq. meter
Pounds/sq. inch	2.307	Feet of water
" " "	2.036	Inches of mercury
" " "	0.06804	Atmospheres
" " "	703.1	Kgs./sq. meter
Quires	25	Sheets
Reams	500	Sheets
Square centimeters	0.1550	Square inches
" "	1.076×10^{-3}	Square feet
Square feet	144	Square inches
" "	0.09290	Square meters
" "	2.296×10^{-5}	Acres
Square inches	6.452	Square centimeters

Multiply	By	To Obtain
Square kilometers	247.1	Acres
" "	10.76×10^6	Square feet
" "	1.196×10^6	Square yards
Square meters	10.76	Square feet
" "	1.196	Square yards
Square miles	640	Acres
" "	27.88×10^6	Square feet
" "	2.590	Square Kilometers
Square yards	9	Square feet
" "	0.8361	Square meters
" "	2.066×10^{-4}	Acres
Tons (long)	1016	Kilograms
" "	2240	Pounds
" "	1.12000	Tons (short)
Tons (metric)	10^3	Kilograms
" "	2205	Pounds
Tons (short)	2000	Pounds
" "	907.18486	Kilograms
Tons of water/24 hrs.	0.16643	Gallons/min.
Watts	0.05692	B.T.Units/min.
"	0.7376	Foot-pounds/sec.
"	1.341×10^{-3}	Horse-power
"	0.01434	Kg.-calories/min.
Yards	0.9144	Meters

Relative Carrying Capacities of Pipe Lines of Equal Smoothness

Prepared by Emil L. Neubling for the Reading Meter Repair Co.

Diameter of Pipes	⅛	¼	⅜	½	¾	1	1¼	1½	2	2½
26										348.81
24										285.53
22										229.20
20									316.23	181.02
18									243.00	139.10
16								371.60	181.02	103.62
15								316.23	154.05	88.18
14							419.80	266.13	129.64	74.21
12							285.55	181.02	88.18	50.48
10						316.23	181.02	114.76	55.90	32.00
9						243.00	139.10	88.18	42.96	24.65
8					371.60	181.02	103.62	65.69	32.00	18.32
7					266.13	129.64	74.21	47.05	22.92	13.12
6					181.02	88.18	50.48	32.00	15.59	8.92
5				316.23	114.76	55.90	32.00	20.29	9.88	5.66
4½				243.00	88.18	42.96	24.65	15.59	7.59	4.35
4			371.60	181.02	65.69	32.00	18.32	11.61	5.66	3.24
3½			266.13	129.64	47.05	22.92	13.12	8.32	4.05	2.32
3			181.02	88.18	32.00	15.59	8.92	5.66	2.76	1.58
2½		316.23	114.76	55.90	20.29	9.88	5.66	3.59	1.75	1.00
2		181.02	65.69	32.00	11.61	5.66	3.24	2.05	1.00	
1½		88.18	32.00	15.59	5.66	2.76	1.58	1.00		
1¼	316.23	55.90	20.29	9.88	3.59	1.75	1.00			
1	181.02	32.00	11.61	5.66	2.05	1.00				
¾	88.18	15.59	5.66	2.05	1.00					
½	32.00	5.66	2.05	1.00						
⅜	15.59	2.76	1.00							
¼	5.66	1.00								
⅛	1.00									

Diameter of Pipes	3	3½	4	4½	5	6	7	8	9	10
48			498.83	371.60	285.55	181.02	123.13	88.18	65.69	50.48
46			448.48	334.09	256.73	162.75	110.70	79.10	59.06	45.38
44			401.31	298.96	229.20	145.63	99.29	70.94	52.85	40.61
42			357.25	243.00	204.50	129.64	88.18	63.15	47.05	36.15
40			316.23	235.57	181.02	114.76	78.06	55.90	41.64	32.00
38		388.41	278.17	207.22	159.23	100.94	68.66	49.17	36.63	28.15
36		339.30	243.00	181.02	139.10	88.18	59.98	42.96	32.00	24.65
34		294.12	210.64	156.92	120.58	76.44	51.99	37.24	27.74	21.32
32		252.76	181.02	134.85	103.62	65.69	44.68	32.00	23.84	18.32
30	316.23	215.10	154.05	114.76	88.18	55.90	38.02	27.23	20.29	15.59
28	266.13	181.02	129.64	96.57	74.21	47.05	32.00	22.92	17.07	13.12
26	221.12	150.41	107.72	80.24	61.66	39.09	26.59	19.04	14.18	10.90
24	181.02	123.13	88.18	65.69	50.48	32.00	21.77	15.59	11.61	8.92
22	145.63	99.29	70.94	52.85	40.61	25.74	17.51	12.54	9.34	7.18
20	114.76	78.06	55.90	41.64	32.00	20.29	13.80	9.88	7.36	5.66
18	88.18	59.98	42.96	32.00	24.65	15.59	10.60	7.59	5.66	4.35
16	65.69	44.68	32.00	23.84	18.32	11.61	7.90	5.60	4.21	3.24
15	55.90	38.02	27.23	20.29	15.59	9.88	6.72	4.81	3.59	2.76
14	47.05	32.00	22.92	17.07	13.12	8.32	5.66	4.05	3.02	2.32
12	32.00	21.77	15.59	11.61	8.92	5.66	3.85	2.76	2.05	1.58
10	20.29	13.80	9.88	7.36	5.66	3.59	2.44	1.75	1.30	1.00
9	15.59	10.60	7.59	5.66	4.35	2.76	1.83	1.34	1.00	
8	11.61	7.90	5.66	4.21	3.24	2.05	1.40	1.00		
7	8.32	5.66	4.05	3.02	2.32	1.47	1.00			
6	5.66	3.85	2.76	2.05	1.58	1.00				
5	3.59	2.44	1.77	1.30	1.00					
4½	2.76	1.83	1.34	1.00						
4	2.05	1.40	1.00							
3½	1.47	1.00								
3	1.00									

Diameter of Pipes	12	14	15	16	18	20	22	24	26	28
48	32.00	21.77	18.32	15.59	11.61	8.92	7.03	5.66	4.63	3.85
46	28.77	19.57	16.47	14.02	10.44	8.02	6.32	5.09	4.16	3.46
44	25.74	17.51	14.71	12.54	9.34	7.18	5.66	4.55	3.73	3.10
42	22.92	15.59	13.12	11.16	8.32	6.39	5.04	4.05	3.32	2.76
40	20.29	13.80	11.61	9.88	7.36	5.66	4.46	3.59	2.94	2.44
38	17.84	12.14	10.21	8.69	6.48	4.98	3.92	3.15	2.58	2.17
36	15.59	10.60	8.92	7.59	5.66	4.35	3.43	2.76	2.26	1.83
34	13.51	9.19	7.74	6.58	4.90	3.77	2.97	2.39	1.96	1.62
32	11.61	7.90	6.65	5.66	4.21	3.24	2.55	2.05	1.68	1.40
30	9.88	6.72	5.66	4.81	3.59	2.76	2.17	1.75	1.43	1.19
28	8.32	5.66	4.76	4.05	3.02	2.32	1.83	1.47	1.20	1.00
26	6.91	4.70	3.96	3.37	2.51	1.93	1.52	1.22	1.00	
24	5.66	3.85	3.24	2.76	2.05	1.58	1.24	1.00		
22	4.55	3.10	2.61	2.22	1.65	1.27	1.00			
20	3.59	2.44	2.05	1.75	1.30	1.00				
18	2.76	1.83	1.58	1.34	1.00					
16	2.05	1.40	1.18	1.00						
15	1.75	1.19	1.00							
14	1.47	1.00								
12	1.00									

Diameter of Pipes	30	32	34	36	38	40	42	44	46	48
48	3.24	2.76	2.37	2.05	1.80	1.56	1.40	1.24	1.11	1.00
46	2.91	2.48	2.13	1.85	1.61	1.42	1.26	1.12	1.00	
44	2.61	2.22	1.91	1.65	1.44	1.27	1.12	1.00		
42	2.32	1.97	1.70	1.47	1.28	1.13	1.00			
40	2.05	1.75	1.50	1.30	1.14	1.00				
38	1.81	1.54	1.32	1.14	1.00					
36	1.58	1.34	1.15	1.00						
34	1.37	1.16	1.00							
32	1.18	1.00								
30	1.00									

The foregoing tables will be found useful in proportioning distribution lines.

Example: To find how many one-half inch pipes can be supplied by a 4-in. line, follow down the ½-in. vertical column to the number opposite 4-in. diameter of the first column, where the number 181.02 is found, which is the number of one-half inch lines that can be supplied by a 4-in. line.

Example: To find how many 12-in. lines can be supplied by a 48-in. line, follow horizontally along the 48-in. diameter of the first column, until you reach the 12-in. vertical column, where the number 32 is found, which is the result desired.

CALCULATION OF AREAS, VOLUMES, SURFACES REDUCED TO SIMPLE TERMS

Mensuration is arithmetic applied to geometry in determining the length of lines, the area of surfaces, and the volume of solids or bodies.

Definitions of geometrical terms, figures and principles. A point (.) has position only. A line (———) has length only. Area has length and breadth. A solid has length, breadth and thickness. Parallel means extended in the same direction, and equidistant at all points. Horizontal means parallel with water level; vertical or perpendicular, parallel with plumb line; diagonal, obliquely across a polygon. (Fig. 4.) Equilateral means, having equal sides. Quadrilateral, having four sides. An angle (Fig. 1) is formed by two straight lines diverging from a common point called the vertex. A right angle (Fig. 2) is formed by two straight lines meeting perpendicularly. An oblique angle is either (acute—Fig. 1) smaller, or (obtuse—Fig. 3) greater than a right angle.

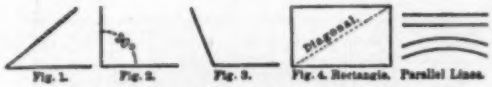


Fig. 1. Fig. 2. Fig. 3. Fig. 4. Rectangle. Parallel Lines.

A plane or plane figure has area or surface only—perfectly even.

A polygon is a plane figure having three or more equal sides.

A triangle is a plane figure bounded by three straight lines.

An equilateral triangle (Fig. 6) has all of its (3) sides equal. An isosceles triangle (Fig. 7) has two of its sides equal. A scalene triangle (Fig. 5) has none of its sides equal. The base is the side on which a geometrical figure is supposed to stand. The least distance between the base and the opposite angle dotted line (Fig. 7) or between parallel lines (Fig. 8) is called the perpendicular or altitude.

To find the area of a triangle. Rule—Multiply base by the altitude and take half of the product. Or, when the three sides are given. From half of the sum of the three sides, subtract each side separately; then multiply the half sum and the three remainders together and extract the square root. Find sq. ft. in a triangle, base 8 ft., altitude 9 ft.

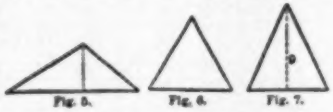


Fig. 5. Fig. 6. Fig. 7.

Answer—$(8 \times 9) \div 2 = 36$.

A parallelogram is a plane figure, bounded by four straight lines, whose opposite sides are equal, as a rectangle, a square, and a rhomboid.

A rectangle is a right angled parallelogram. A square is an equilateral rectangle. A rhomboid is an oblique angled parallelogram.

To find the area of a parallelogram. Rule—Multiply the length by the width.

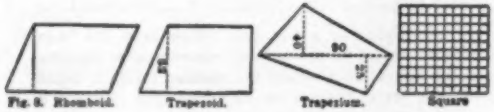


Fig. 8. Rhomboid. Trapezoid. Trapezium. Square

How many sq. ft. in a rectangle 17 by 24?

Answer—$17 \times 24 = 408$ sq. ft.

In a (square) floor 10 by 10?

Answer—$10 \times 10 = 100$ sq. ft.

Note—Dividing the area of a rectangle by one side gives the other side—if unknown.

A *trapezoid* is a quadrilateral having two of its sides parallel. To find its area. Rule—Multiply its average length by the width.

How many sq. yd. in a garden whose parallel sides are 60 and 80 yd., and width 52 yd.?

Answer—$(60 + 80 \div 2) = 70$; then, $70 \times 52 = 3{,}640$ sq. yd.

A *trapezoid* is a quadrilateral having two of its sides parallel.

To find its area. Rule—Form two triangles by a diagonal line, then multiply diagonal by sum of perpendiculars and take half of product.

Find sq. rods in field shaped like a trapezium, whose diagonal is 90 rods, and perpendiculars (25 and 40) 65 rd.

Answer—$90 \times 65 = 5850 \div 2 = 2925$ rd.

A *rightangled triangle* has one right angle. Its longest side is called hypotenuse, and the other two, base and perpendicular or altitude. To find its area. Rule—Multiply the base by the perpendicular and take half of the product.

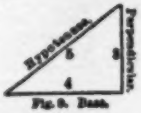


Fig. 9. Data.

How many square rods in a triangular field whose base is 70 rods and the perpendicular, 48 rods?

Answer — $(70 \times 48) \div 2 = 1680$ square rods.

Properties of the rightangled triangle. The square of the hypotenuse equals the sum of the squares of the base and the perpendicular. From this principle — illustrated by Fig. 10—we derive the following rules.

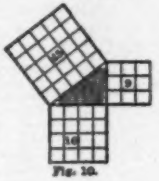


Fig. 10.

To find the hypotenuse. Rule—Add the square of the base and the square of the perpendicular, and of the sum extract square root.

A and B start from the same point. A going 4 miles due west and B, 3 miles due north; how far apart are they then?

$4^2 = 16$
$3^2 = 9$
$\sqrt{25} = 5$

Answer—5 miles.

The square of 4 (base)$=16$; of 3 (perpendicular)$=9$; the square root of their sum $(25)=5$, the hypotenuse.

To find the base or perpendicular. Rule—From the square of the hypotenuse, subtract the square of the other given side, and of their difference extract the square root.

Find the perpendicular of a triangular field whose hypotenuse is 75 rods, base 60 rods. Answer—45 rods.

$75^2 = 5625$
$60^2 = 3600$
$\sqrt{2025} = 45$

Note—To find the difference between the squares of two numbers, simply multiply their sum by their difference.

To find the side of a square equal in area to any given quantity. Rule—Extract the square root of the given quantity.

Thus, the dimensions of a square field containing 4000 square rods must be $(\sqrt{4000} = 63.246)$ 63¼ rods, nearly. Proof: $63\frac{1}{4}^2 = 4000 +$

To find the diagonal of a square. Rule—Multiply one side of the square by 10, diminish the product by 1% of itself and divide remainder by 7.

What is the diagonal of a field 35 rods square?

This is a simple way of finding the hypotenuse of a triangle whose base and perpendiculars are equal.

$35 \times 10 = 350$.
1% of $350 = 3.5$
$7)346.5$
Ans. (rd.) 49.5

The Circle

A circle is a plane figure bounded by a curved line, (1, 1, 1, 1) called circumference, every point of which is equally distant from

tne center. The diameter is a straight line (2, 2) across a circle, through its center. The radius is a straight line (3) from the center to the circumference. An arc is any part of the circumference (5, 5). A chord, a straight line (4) joining ends of an arc. A tangent (6) touches circum. without cutting it. A segment is space (C) enclosed by arc and chord. A sector, space (B) enclosed by two radii and arc. A quadrant (A) is 90° or the fourth part of circle. A circle is divided into 360°; from X to Y is 45°; from X to Z, 90°. A sextant is one-sixth of a circle.

Elements of the Circle.

To find the *circumference* of a circle, the diameter being given. Rule—Multiply the diameter by 3 1/7; for greater accuracy, by 3.1416.

Find circumference of bicycle wheel; diam. 28 in.

Answer—28 × 3 1/7 = 88 in.

To find the *diameter* of a circle, the circumference being given. Rule—Divide the circumference by 3 1/7, or multiply it by .3183.

Circumference of a tree 144½ in., find diam.

Answer—144.5 × .3183 = 46 in.

To find the *area* of a circle. Rule—Multiply the square of the diameter by .7854; or the square of the radius by 3.1416; or the square of the circumference by .07958.

Find the area of a piston 20 in. in diam.

Answer—20^2 × .7854 = 314.16 sq. in.

Over how many sq. ft. can a cow graze, staked to a rope 50 ft. long? Here, 50 feet is the radius.

Answer—50^2 × 3.1416 = 7854 sq. ft.

To find the *radius* of a circle, the area being given. Rule—Multiply the area by .3183 and extract the square root of the product.

Find length of halter, tied to stake, that will enable horse to graze on 1 acre.

Answer—Square feet in acre, 43560 × .3183 = 13865; $\sqrt{13865}$ = 117¾ ft. long.

Note—The circumference of a circle is 3.1416 times greater than the diameter. The number 3.1416 (called Pi); its reciprocal, .3183; its 4th part .7854, its 6th part .5236, and others, should be committed to memory as they are indispensable factors in computing the areas and volumes of circular figures and bodies.

To find the *area of a sector* of a circle. Rule—Take such a part of the circle as the degrees in the given arc, are part of 360. Thus, a sector whose arc is 40°, contains 40/360 or 1/9 of the area of the circle.

To find the side of the greatest square that can be inscribed in a given circle. Rule—Multiply the diameter of the circle by .707; or the circumference by .225.

The diameter of a log is 24 inches; how large a sill can be cut from it?

24 × .707 = 17 in. square, nearly.

To inscribe the greatest equilateral triangle. Rule—Multiply the diameter of the circle by .886.

Side of greatest inscribed hexagon equals the radius of a circle.

To find the diameter of a circle that will inscribe a given square. Rule—Multiply the side of the desired square by 1.414.

What must be diam. of a log to cut a sill 12 in. sq.?

Answer—12 × 1.414 = 17 in.

The area of the greatest square inscribed in a given circle is exactly ½ of the area of the least square circumscribed about the same circle—or the square of its diameter.

To find the area between the two *concentric circles*. Rule—Take the difference between the area of each circle. A simpler way is to multiply the sum of the two diameters by their difference, and the product by .7854.

Find the area included between two concentric circles whose diameters are 30 and 50 inches. (80, sum; 20, dif.)

Answer—20 × 80 = 1600 × .7854 = 1256.64 sq. in.

To find the diameter of a circle whose area is equal to the area of a given square. Rule—Multiply one side of the given square by 1.1284.

To find the side of a square whose area is equal to the area of a given circle. Rule—Multiply the diameter of the given circle by .8862.

To find the diameter of three greatest equal circles that can be inscribed in a given circle. Rule—Multiply the diameter of the given circle by .464.

Find the diameters of the three greatest circles that can be inscribed in a circle 50 in. in diam.

Answer—50 × .464 = 23.2 in.

An *ellipse* is a plane figure bounded by an oval curved line and has a long and a short diameter or axis.

To find its circumference. Rule—Multiply the sum of the two diameters by 3.1416, and take half of the product.

Ellipse.

Find the circumference of an ellipse whose diameters are .41 and 29 ft.

(41 + 29) = 70 × 3.1416 ÷ 2 = 110 ft. nearly.

To find the *area of an ellipse*. Rule—Multiply the product of the two diameters by .7854.

How many square ft. are there in an elliptical platform whose diameters are 60 and 40 ft.?

60 × 40 = 2400 × .7854 = 1885 sq. ft. nearly.

Polygons

To find the area of polygons, having equal sides and equal angles. Rule—Multiply the square of one of the equal sides—of a triangle, by .433; of a pentagon, by 1.7205; of hexagon, by 2.5981; of octagon, by 4.8284.

One side of an equilateral triangle is 30 inches, and of an octagon, 10 in.

Find sq. in. in each.

30^2 × .433 = 389.7 in. T; 10^2 × 4.824 = 482.84 in. O.

Trigonometric Functions.

For the benefit of those who intend to study trigonometry and surveying, this illustration is inserted here. It will be an advantage and saving of time to be already familiar with the terms and the functions of the science when beginning its study.

P M, sine.
O M, cosine.
A T, tangent.
B S, cotangent.
O T, secant.
O S, cosecant.
M A, versed sine.
B N, conversed sine.

Cubes, Cones, Pyramids, Spheres,

A *cube* is a solid body, having six equal square sides. To find its area. Rule—Multiply area of one side by 6. To find its volume. Multiply the length, the breadth and the thickness together.

Cube.

Find sq. in. in surface of a 12 in. cube.

Answer—12^2 × 6 = 864.

How many cubic in. in a cubic foot?

Answer—$*12^3$ = 1728.

Find cu. ft. in a cu. mile.

Answer—5280^3 = 147197952000.

A *parallelopiped* is a solid body whose six faces are all rectangles. To find its area. Rule—Add areas of its six sides. To find its volume. Same as the cube. How many cubic feet in a wagon bed 10½ feet long, 3 ft. wide and 1¼ ft. deep?

Parallelopiped.

Answer—10½ × 3 × 1¼ = 39⅜.

A *prism* is a solid having three or more rectangular sides, whose ends or bases are parallel plane figures. To find its area. Rule—Add areas of the sides and ends. To find its volume. Multiply the area of one end by the length.

Prism.

Find the area of a triangular prism, each of whose three sides are 10 by 25 inches.

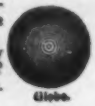
Answers—836.6 sq. in.

10^2 × .433 × 2 = 86.6 sq. in. in area of the two ends. 10 × 25 × 3 = 750 sq. in. area of sides. 86.0 + 750 = 836.6.

How many cubic inches in above prism, 10 by 25 inches?

Answer—10^2 × .433 = 43.3 × 25 = 1082½ cu. in.

A *globe* or *sphere* is a solid body, bounded by a uniformly curved surface. To find its area. Rule—Multiply the square of diameter by 3.1416; or the square of the circumference by .3183. To find its volume. Multiply the cube of diameter by .5236.


Globe.

How many square in. in the surface; and how many cubic in. in the volume of a globe 12 in. in diameter?

Answer—904.78 cu. in. $12^2 \times 3.1416 = 452.39$ sq. in. $12^3 \times .5236 = 904.78$ cu. in.

How many cubic miles in the earth, its diameter being nearly 8000 miles?

Answer—$2000^3 \times .5236 = 268083200000$ cubic mi.

Find greatest cube inscribed in a 26 in. globe.

Answer—$26 \times .577 = 15$ in.

To find the dimensions of a cube, equivalent in volume to a given globe. Rule—Multiply the diameter of given globe by 806.

To find the diameter of a globe, equivalent in volume to a given cube. Rule—Multiply one side of the cube by 1.2407.

A *cylinder* is a round body of uniform diameter whose ends are parallel plane figures. To find its area. Rule—Multiply the circumference by the length and to the product add the areas of both ends. To find its volume. Multiply the area of one end by length.

Cylinder.

Find the area of a cylinder 30 inches in circumference and 40 inches long.

Answer—1343.24 sq. in.

$30 \times 40 = 1200$ sq. in. in convex surface.

$30^2 \times .07958 \times 2 = 143.24$ sq. in. in the two ends.

Find cubic in. in a cylinder, diameter, 20 in., length 50 in.

Answer—$20^2 \times .7854 \times 50 = 15708$ cu. in.

A *cone* is a solid, which has a circular base and tapers uniformly to a point called vertex.

A *pyramid* is a solid, resembling a cone, having three or more triangular sides.

Cone. Pyramid.

To find the area of a *cone or pyramid*. Rule—Multiply the circumference or perimeter of the base by the slant height, and to half of the product, add the area of the base.

Find the area or surface of a cone whose circumference at base is 40 in., and slant height 50 in.

Answer—1127.33 sq. in.

$50 \times 40 \div 2 = 1000$ sq. in. in convex surface.

$40^2 \times .07958 = 127.33$ in. base.

To find the volume of a cone or pyramid. Rule—Multiply the area of the base by the height and take ⅓ of the product.

How many cubic feet in a 6 sided pyramid, 10 ft. high, whose perimeter, at base is 15 ft. or each side 2½ ft.?

Answer—54.13 cu. ft.

$2\frac{1}{2}^2 \times 2.598 = 16.24$, area of base. $10 \times 16.24 \div 3 = 54.13$.

Find cu. in. in a cone whose height is 12½ in., and diameter of base 10 in.

Answer—$10^2 \times .7854 = 78.54$ area of base. $78.54 \times 12\frac{1}{2} \div 3 = 32.25$ cu. in.

The solid contents of the cone, globe, cylinder and the cube, all of equal dimensions, are in the ratio of 1, 2, 3 and 3.82 respectively. Thus, taking 1 foot as the height and the diameter; the cone contains .2618; the globe .5236, and the cylinder .7854 of a cubic foot. The cube equals 1 cu. ft.

The *frustum of a cone or pyramid* is the part which remains after cutting off the top, parallel to the plane of the base. To find the area of a frustum. Rule—Multiply the sum of circumferences, or perimeters, by the slant height, and to half of the product, add the area of each base.

Frustums.

Find the *area of a frustum* of a cone, whose slant height is 40 in., its greater circumference, 30 in., and its smaller one, 10 in.

Answer—879.58 sq. in.

$30 + 10 \times 40 \div 2 = 800$, sides. $30^2 + 10^2 \times .07958 = 79.58$, area of bases.

To find the *volume of any frustum*. Rule—Square both ends of one side, if angular, or the diameters of both ends or bases, if round. To the two squares add the product of the given ends or diameters; ⅓ of this sum will be the area of the average base of the frustum of a square pyramid, which multiplied by .7854 equals area of average base of frustum of a cone; multiplied by .433, of a three sided frustum, by 1.7205, of a five sided fr., by 2.5981, of a six sided frustum, by 4.8284, of an eight sided frustum. For volume: multiply average area by perpendicular height.

Find the volume or capacity of a round tank whose diameter is 15 ft. at base, 12 ft. at top, and 10 ft. deep. Ans.—14.37 cu. ft.

$12^2 = 144$ } $183 \times .7854 = 143.73$ sq. ft., area
$15^2 = 225$ } of av. base of Fr. of cone.
$12 \times 15 = 180$

3)549 (183, area of av. base of F. of sq. pyr.

$143.73 \times 10 = 1437.3$ cu. ft. $\times 7.48 = 10751$ gallons.

Find sq. ft. of lumber in a wagon tongue; large end, 4½ in. sq., small end, 2½ in., length, 9 ft. (108 in.).

Answer—$4\frac{1}{2} + 2\frac{1}{2}^2 + (4\frac{1}{2} \times 2\frac{1}{2}) \div 3 = 12\ 7/12$ sq. in., area of average base; $12\ 7/12 \times 108 = 1359$ cu. in. $\div 144 = 9\ 7/16$ sq. ft.

How many cu. ft. in a straight log, whose diameter at large end is 3 ft., small end, 2 ft., length 12 ft?

Answer—$3^2 + 2^2 + (3 \times 2) \div 3 \times .7854 = 4.974$ sq. ft., area of average base; $4.974 \times 12 = 59.69$ cu. ft.

A *spheroid* or elongated globe has a fixed and a revolving axis. To find its area. Rule—Multiply the revolving axis by the fixed axis, and that product by 3.1416. To find its volume. Rule—Multiply the square of the revolving axis by the fixed axis and that product by .5236. Find area, also the volume of spheroid; revolving axis, 20 in., fixed, 30 in.

Spheroid

$20 \times 30 \times 3.1416 = 1884.96$ sq. in. in area.

$20^2 \times 30 \times .5236 = 6283.2$ cu. in. in volume.

A *cylindrical ring* is formed by bending a cylinder. To find its area. Rule—Multiply sum of inside diam. and thickness of ring, by thickness, and the product by 9.87. To find its volume. Rule—Multiply sum of inside diam. and thickness by square of thickness, and product by 2.467.

Ring.

Find the area, also the volume of a ring whose inner diameter is 15 inches, and whose thickness is 5 inches.

$(15 + 5) \times 5 \times 9.87 = 987$ sq. in. in area. $(15 + 5) \times 5^2 \times 2.467 = 1233.5$ cu. in vol.

To find the dimensions of *greatest cube that can be inscribed in a given globe*. Rule—Multiply the diameter of the globe by .577.

The above material has been drawn from "Ropp's Calculator"—an extremely useful and inexpensive little booklet published by C. Ropp & Sons, of Chicago.

CHART FOR DETERMINATION OF PUMPING COSTS

This chart is used for determining the power cost of pumping water per thousand gallons when the total head, wire-to-water efficiency and power rate are known. In using this chart a ruler is placed from line A (Power Rate in Cents per Kilowatt Hour) to line B (% Wire-to-Water Pump Efficiency). A pin or pencil point is placed against the edge of the ruler on the Pivot Line and the ruler is then pivoted to the proper point on line D (Total Head in Feet). The Cost for Power per Thousand Gallons can then be read directly from line C at the left of the chart. *(Courtesy Edward E. Johnson, Inc.)*

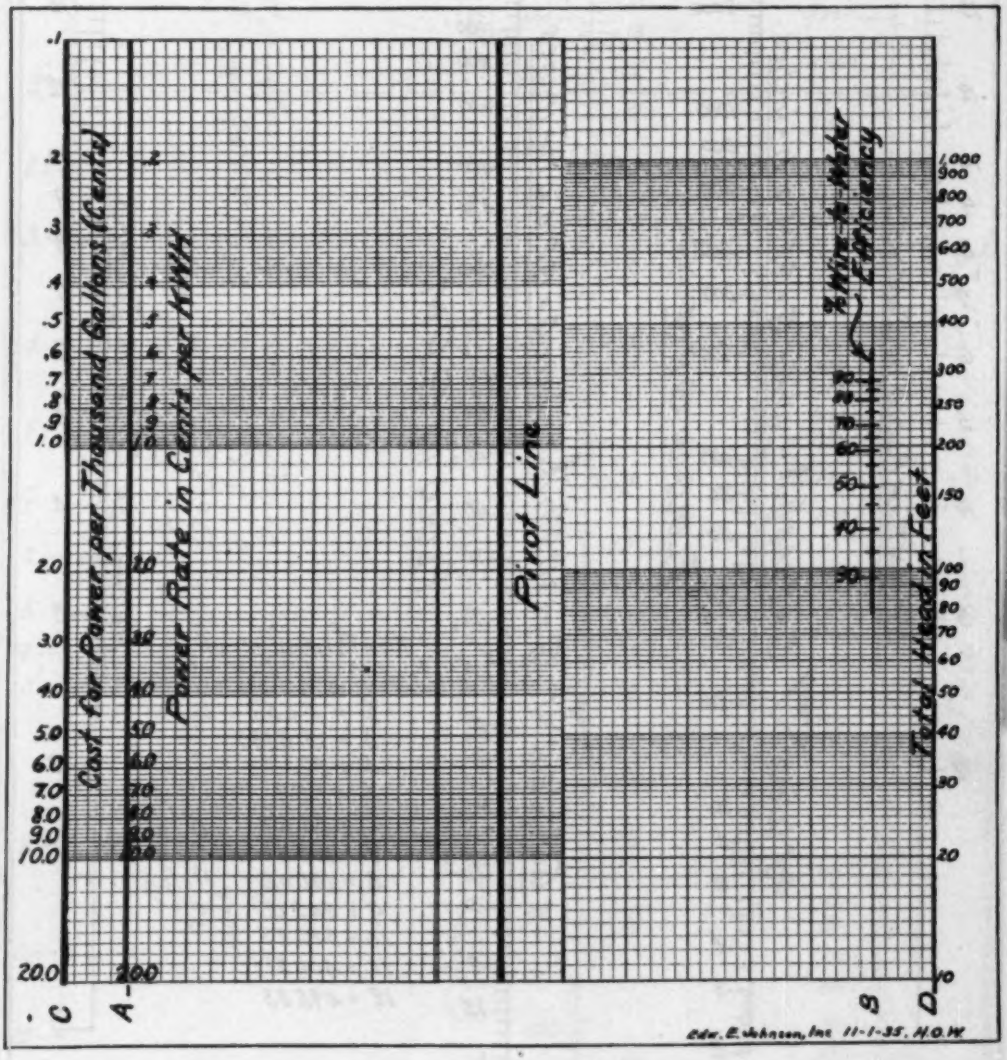
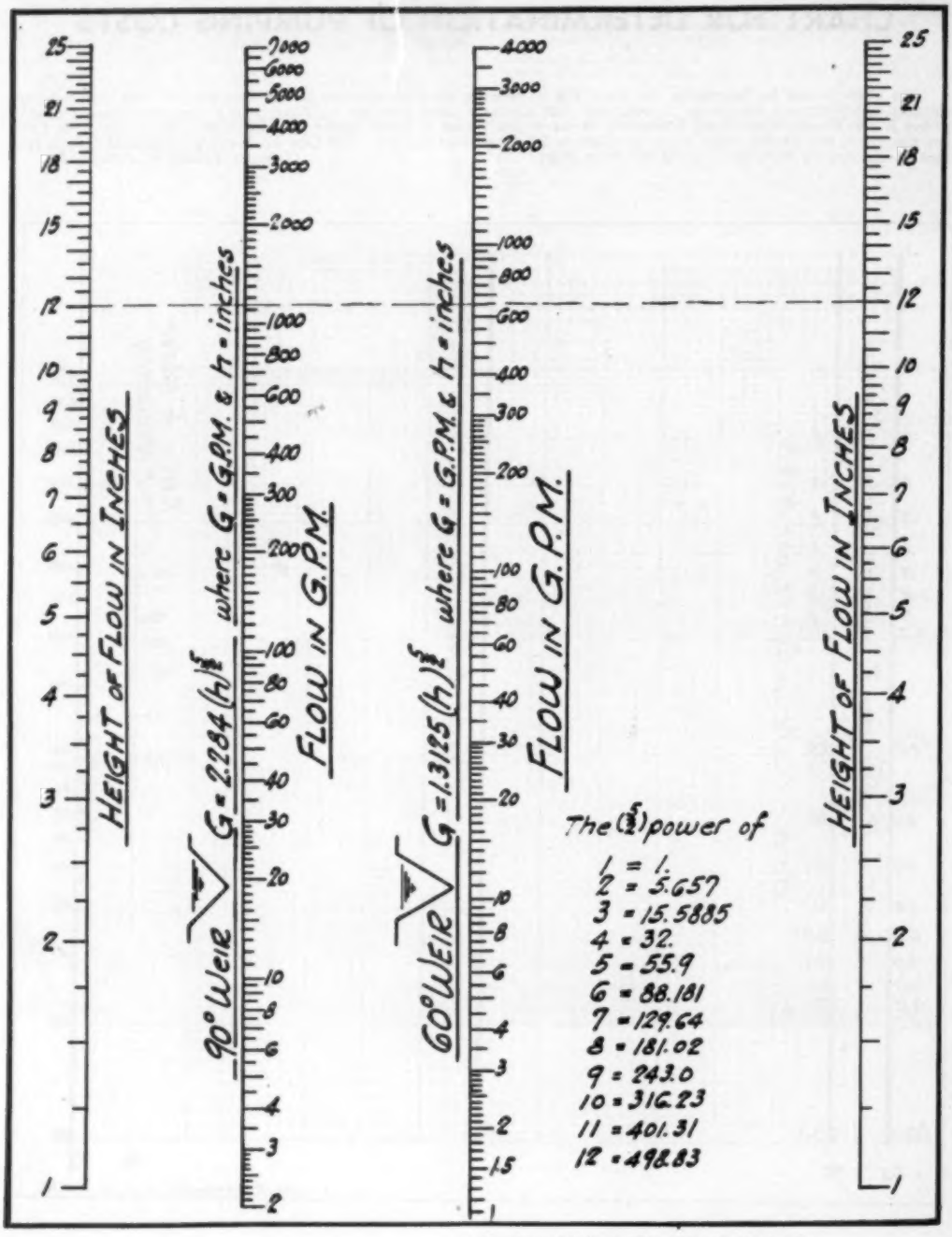
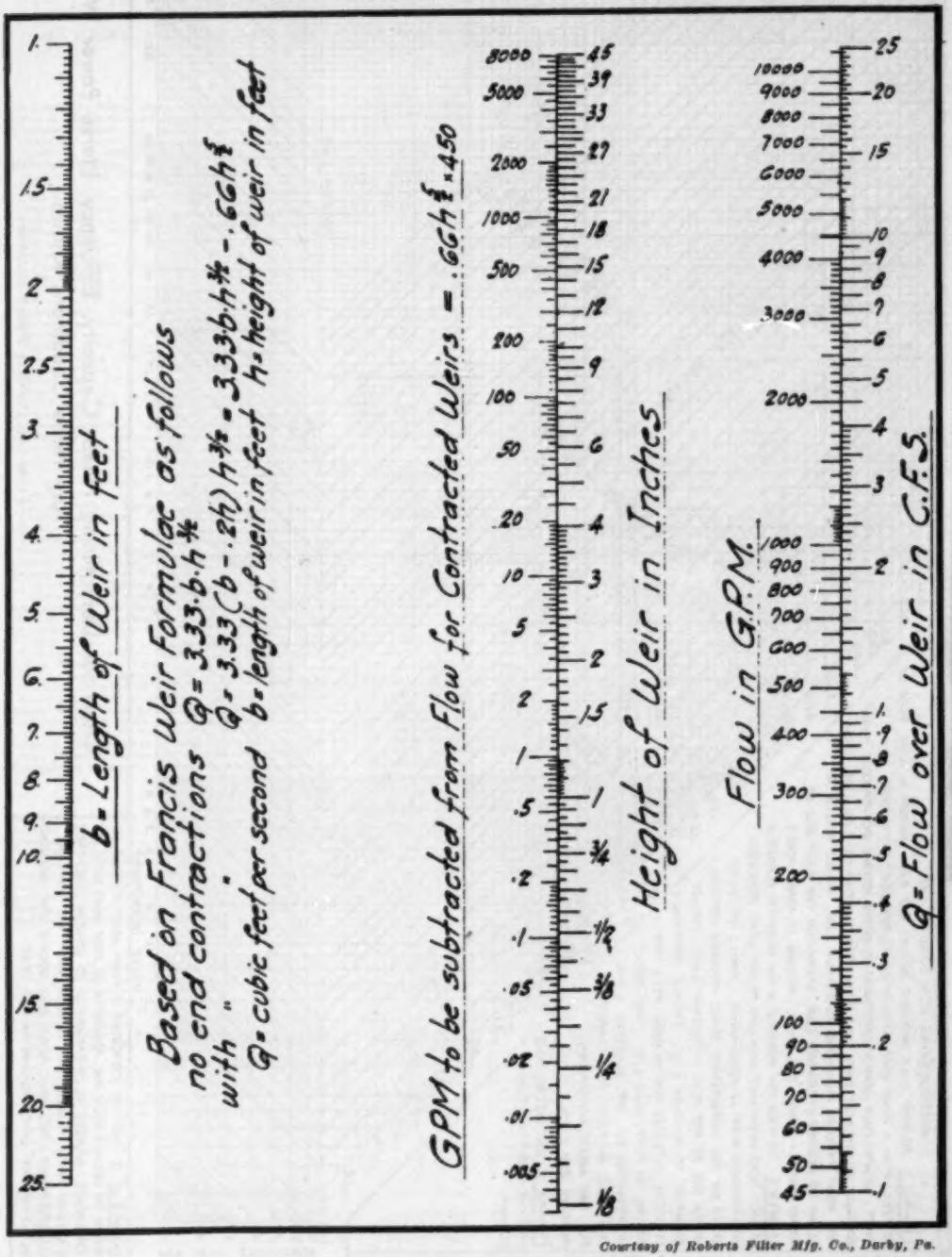

Cost for Power per Thousand Gallons (Cents)
Power Rate in Cents per KWH
Pivot Line
% Wire-to-Water Efficiency
Total Head in Feet
Edw. E. Johnson, Inc 11-1-35. H.O.W.

CHART FOR CAPACITY OF 60° AND 90° V-NOTCH WEIRS



Courtesy of Roberts Filter Mfg. Co., Darby, Pa.

CHART FOR CAPACITY OF RECTANGULAR WEIRS


b = Length of Weir in Feet
Based on Francis Weir Formulae as follows
no end contractions Q = 3.33 b h ^3/2
with " Q = 3.33 (b - .2h) h ^3/2 = 3.33 b h ^3/2 - .667 h ^5/2
Q = cubic feet per second b = length of weir in feet h = height of weir in feet
GPM to be subtracted from Flow for Contracted Weirs = .667 h ^5/2 x 450
Height of Weir in Inches
Flow in G.P.M.
Q = Flow over Weir in C.F.S.

Courtesy of Roberts Filter Mfg. Co., Darby, Pa.

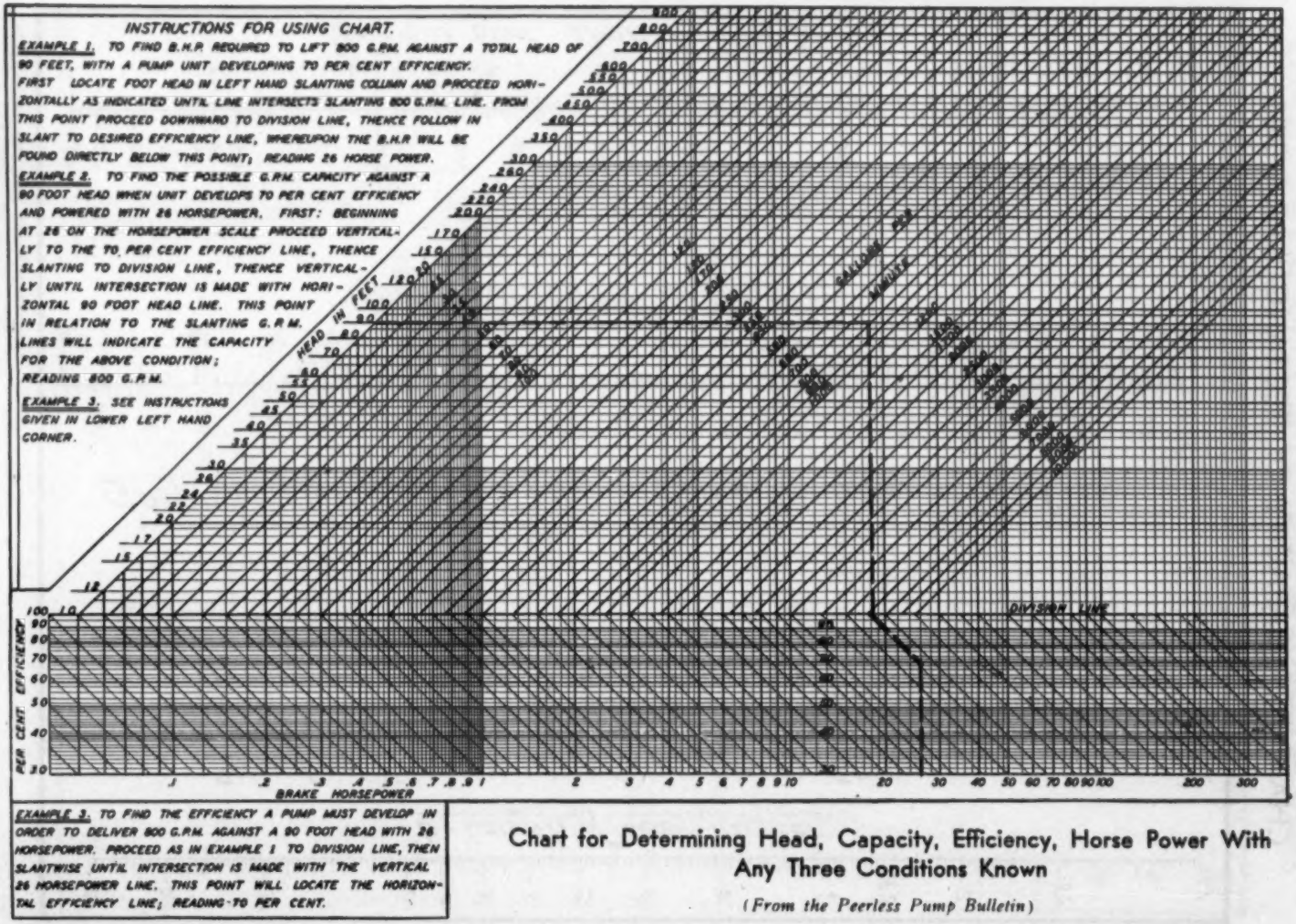

INSTRUCTIONS FOR USING CHART.
EXAMPLE 1. TO FIND B.H.P. REQUIRED TO LIFT 800 G.P.M. AGAINST A TOTAL HEAD OF 90 FEET, WITH A PUMP UNIT DEVELOPING 70 PER CENT EFFICIENCY. FIRST LOCATE FOOT HEAD IN LEFT HAND SLANTING COLUMN AND PROCEED HORIZONTALLY AS INDICATED UNTIL LINE INTERSECTS SLANTING 800 G.P.M. LINE. FROM THIS POINT PROCEED DOWNWARD TO DIVISION LINE, THENCE FOLLOW IN SLANT TO DESIRED EFFICIENCY LINE, WHEREUPON THE B.H.P. WILL BE FOUND DIRECTLY BELOW THIS POINT; READING 26 HORSE POWER.
EXAMPLE 2. TO FIND THE POSSIBLE G.P.M. CAPACITY AGAINST A 90 FOOT HEAD WHEN UNIT DEVELOPS 70 PER CENT EFFICIENCY AND POWERED WITH 26 HORSEPOWER. FIRST: BEGINNING AT 26 ON THE HORSEPOWER SCALE PROCEED VERTICALLY TO THE 70 PER CENT EFFICIENCY LINE, THENCE SLANTING TO DIVISION LINE, THENCE VERTICALLY UNTIL INTERSECTION IS MADE WITH HORIZONTAL 90 FOOT HEAD LINE. THIS POINT IN RELATION TO THE SLANTING G.P.M. LINES WILL INDICATE THE CAPACITY FOR THE ABOVE CONDITION; READING 800 G.P.M.
EXAMPLE 3. SEE INSTRUCTIONS GIVEN IN LOWER LEFT HAND CORNER.
HEAD IN FEET
PER CENT EFFICIENCY
BRAKE HORSEPOWER
DIVISION LINE
GALLONS PER MINUTE
EXAMPLE 3. TO FIND THE EFFICIENCY A PUMP MUST DEVELOP IN ORDER TO DELIVER 800 G.P.M. AGAINST A 90 FOOT HEAD WITH 26 HORSEPOWER. PROCEED AS IN EXAMPLE 1 TO DIVISION LINE, THEN SLANTWISE UNTIL INTERSECTION IS MADE WITH THE VERTICAL 26 HORSEPOWER LINE. THIS POINT WILL LOCATE THE HORIZONTAL EFFICIENCY LINE; READING 70 PER CENT.

Chart for Determining Head, Capacity, Efficiency, Horse Power With Any Three Conditions Known

(From the Peerless Pump Bulletin)

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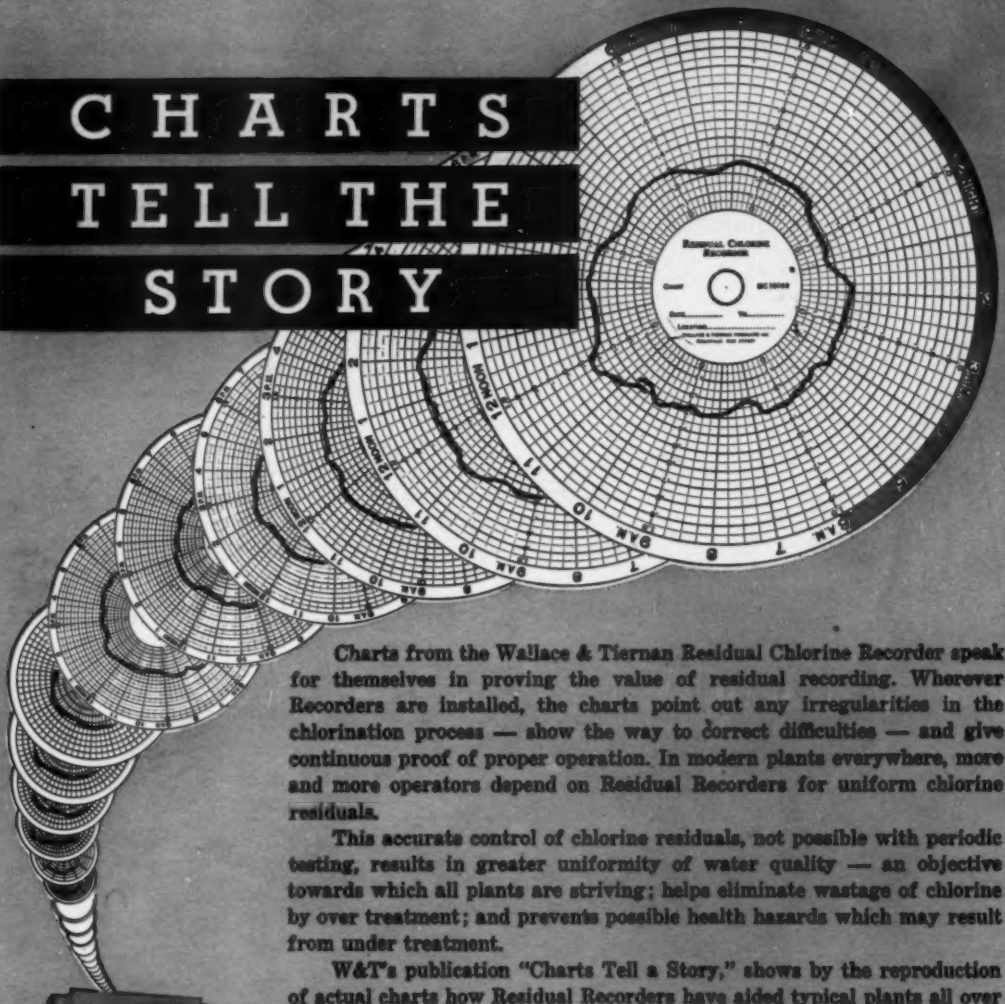

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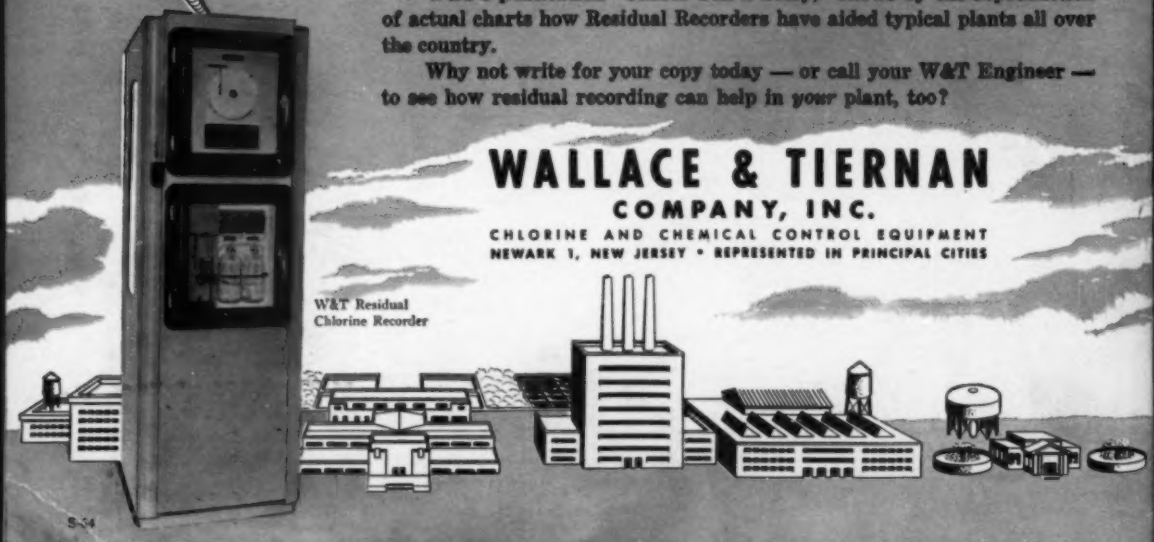

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